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SCIENTIFIC METHOD IN EDUCATION

BY

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EDITOR'S INTRODUCTION

PRIOR to the time of Horace Mann and the other educational revivalists, the improvement of teaching practice was so gradual that it scarcely attracts the attention of the educational historian. Tradition clutched the classroom firmly. Individual experience, with its endless trial and error, wove new patterns of procedure, but not many. A single inspired writer of textbooks with a new plan for organizing subject-matter had more professional effect than the numerous innovating but isolated teachers who may have discovered desirable changes. Teachers were not coöperative. They were not a group with a common association which permitted them to share one another's successes.

With the period of educational revival, the profession acquired organization. It was crude as compared with present standards, but it was epoch-making in its usefulness. Teachers were brought together for study and discussion. They exchanged experiences. Practice was cross-fertilized and enriched by exchange of ideas.

Specialized leaders were called into service as the supervisors or managers of State and city school systems. Their function was to discover good teaching methods and to disseminate them among their associates. But the good went beyond the exchange and appraisal of individual skills. Some of the leaders had looked outside their own domains into the systems of adjoining States, and a few had traveled in Europe to note the working of a different tradition in foreign school systems. Contrasts are always unsettling. They raise questions and encourage borrowing and adaptation. But progress under such conditions remains empirical, being based on mere personal experience or observation. It was the exchange of practical technique among teachers which led to the new results. No new mode of inquiry had been utilized.

With the beginning of the last quarter of the nineteenth century, a new influence was brought to bear upon American education — the theories of European philosophers where general concepts were applied to the psychology and pedagogy of childhood. A considerable number of American educators had pursued their university training in European universities, particularly those of Germany, and these eager and enthusias-

tic students of education brought the speculations of Herbart and Froebel to bear upon American practice. Other philosophies became a part of current discussion. Americans soon developed, largely through reflection upon their own experiences, educational philosophies of their own. It was a period of great stimulation and heightened experimentation. Infancy, childhood, youth, and adolescence began to be observed under the promptings of diverse theory and practice, preparing the way for something better than the appeal to ordinary experience and deductive applications of novel theories.

Early in the twentieth century the wedges of inquiry and experimentation had pushed their way into professional thinking, promising another significant turn in the road of professional progress.

A discriminating analysis of the kinds of thinking which have characterized the sessions of educational leaders, particularly during the past ten years, would probably show few new varieties of thought. It does, however, reveal two very significant facts. First, the usual empirical and speculative thinking of teachers has lost its dominance, its place being taken by reports and discussions based upon inquiries made in a rigid

scientific spirit and pursued by the accurate modes of modern science. Second, the professional mind itself has developed a new sensitiveness, becoming tremendously receptive to suggested reforms based on scientific inquiry and exceedingly skeptical of proposals which do not possess a firm fact basis.

From such observations it is clear that the scientific movement in education is well under way. Its promise can scarcely be predicted in detail. We are, indeed, at an important turn in the road of educational advance, perhaps the most significant in all our history. From every field of science, both natural and humanistic, we are taking specific scientific procedures and utilizing them to understand the determining factors in education; in addition we are developing special scientific ingenuities of our own.

To understand the contemporaneous scientific movement in the educational profession is not a simple matter. Yet such comprehension is the need of every teacher. An inclusive yet simple summary is required. To this end the book here presented has been written. It records the various modes of advance with adequate concrete illustrations; it leads us into an understanding of our present circumstance with its apparent con-

flict and confusion; it explains the canons of sound scientific procedure which are to influence us from now on. It should be read by every alert and progressive teacher.

SCIENTIFIC METHOD IN EDUCATION

I

INTRODUCTION

TO-DAY more than ever before science is looked upon as the giver of gifts, the panacea for all ills. The mythical man in the street wears shoes whose composition soles are made by a new scientific process; they were sold to him through scientific advertising or by a scientific sales talk. He climbs into his motor which was but recently the scientific wonder of the age, and enjoys the comfort afforded by his balloon tires, the most recent gift of science to transportation comfort. When he comes to his home he "listens in" on some distant speech or concert over his new radio set, the latest marvel of science.

So popular has the term become that to call a product scientific is to sell it by the million, if we are to judge from the advertising which now comprises so large a part of our newspapers and magazines. And in no field has the term been used with greater prodigality than in the field of

human thought and action. The older 'sciences' of palmistry and phrenology are decked out in new guise so that we have the science of reading character at sight, the science of personality-building, the science of auto-suggestion, and many others; and there are scientific memory courses, and scientific lectures on sure and easy ways to secure health, happiness, and success.

As a result of the widespread publicity given to such charlatanism through the rapid expansion of advertising, the word 'scientific' has come to mean to the man in the street a kind of combination of the highbrow, the up-to-date, and the crooked. And science is a kind of scheme that can be counted on to get results by a short-cut route. We often hear the phrase, "He's got it down to a science," which may apply to making train connections to get to the office on time, or to breaking the law consistently without being caught.

It is doubtful if those engaged in the profession of teaching are influenced particularly by this widespread, loose usage, though it may sometimes creep into their non-professional vocabulary. Nevertheless, there are two ways that the term, if thoughtlessly used, can bring numberless disasters in its wake.

The first of these is a too greedy acceptance of what purports to be scientific in the educational field. It has been known to happen that a tentative hypothesis of a scientific worker has been pounced upon by a school administrator who wished to profit by whatever science had to offer, or who may have had less commendable motives, with the result that the smooth-running of a school has been interfered with and no advantage gained. The history of the measurement movement in education, for example, could furnish many instances of such action, as could another very excellent movement, namely, that for bettering the health of school children. Without adequate knowledge or preparation, the incorporation of the newer findings of science brings about more harm than good. People come to refer to them as 'half-baked' schemes, and the cause of progress is set back many years.

The other way that a lack of proper understanding of the meaning of Science can work a positive harm is by forswearing her and all her works. This is the attitude of the reactionary who distrusts innovations, who determinedly falls back upon his old and habitual way of doing things, and cannot be forced out of his groove.

It is clear that positive harm can come from

either of these two attitudes. And although they are in part due to temperamental differences, they are to a still greater extent due, I believe, to ignorance. Those who have worked up to their present positions through gradual promotion, and whose training was in the normal school of the older type, may have had little opportunity to comprehend what is meant by the scientific method particularly as applied to educational problems. Their high-school science courses probably supplied little. Their normal course was taken up with methods of teaching usually of a formal character, in that they learned ready-made principles, and with instruction in the content of the subjects they were to teach. Since that time, they have been busy in the day-to-day tasks of instruction and administration, and few have had any opportunity to break away and become thoroughly grounded in scientific study.

Those whose preparation has been more recent, or who have come by way of the college, have, in many cases, fared little better. College courses in the sciences — physics, chemistry, biology, etc. — are all too often actually little more than training in following directions as given in the laboratory manual, half-hearted note-taking during lectures, and copying the notes or 'find-

ings' of others. Even when college teachers of science are aware of these dangers and do what they can to guard against them, they are too busy covering the required work to assist pupils to generalize their experience to see that it applies in other fields. They all too frequently have no realization, themselves, that the method of science can be brought to bear on the problems of education. No wonder students leave college regarding the scientific method as applicable merely to certain particular parts of the curriculum rather than as *a method of approaching any subject-matter.*

When the sciences are taught in an unscientific spirit, it is too much to expect that the usual courses in education will fill the breach. History and Principles are still in many places the maximum requirement, and the course too easily follows the old track. The addition of a few other courses likewise fails to inculcate the scientific viewpoint in such a way that students can appreciate it, or use it to grapple with educational problems they are soon to meet.

Clearly no book can take the place of rigid scientific training; and certainly a book of this size can do no more than point out certain facts, and show certain relationships. But even in

these few pages it should be possible to clarify the thinking of students in regard to the relationship of science to education, and to assist teachers and administrators to avoid being either wild-eyed innovators or dyed-in-the-wool conservatives when they come to a consideration of the contributions of science to education.

As has been said earlier, the word 'science' is sadly misused in common speech. Literally, it means 'knowledge' (Latin, *scientia*), though certain quite legitimate, specific meanings have been attached to it. It is more commonly defined as a systematic and orderly arrangement of knowledge referred to the general truths or principles from which it is derived. More narrowly still, it is used to refer to certain branches of learning such as chemistry, physics, and biology.

But this idea of orderly arrangement quite overlooks the method of acquisition of the knowledge which is to be arranged in orderly fashion. It is the *method* of science which is by far the most important thing about it. One's appreciation of the meaning of this word is likewise enhanced by an understanding of its derivation. Etymologically, it means a 'pursuit of' (Greek, *methodos*). The scientific method, then, means literally the pursuit of knowledge. But it is a particular kind

of pursuit, for a method is a way of reaching a given end by a series of acts that tend to secure it. It is an orderly procedure or process.

To this extent, therefore, the word is applicable to any number of situations. These may be quite objective, for one may speak of a method of attack used in war, or on a smaller scale of the method of attack of a salesman in the effort to sell his goods. Or, we speak of the method of attack upon a problem, the solution of which we seek. In education, the word is usually confined to classroom procedure, so that we consider methods of teaching geography or spelling. Or we use the term more broadly to apply to any of a number of school subjects and speak of the method of measurement, the developmental method, or the problem-project method. In all of these cases, we are considering an orderly procedure or process in the direction of a given end, whether that end be taking a city, selling some goods, or teaching children.

In this book, we are discussing the application of the scientific method to educational problems. It will be necessary to give detailed consideration to this method as it has been developed in the process of the pursuit of knowledge. But before doing this, we shall ask what other ways man-

kind has used to acquire the knowledge sought.

This seeking has seldom come except as difficulties are felt. In the face of the multitude of difficulties confronting every one — difficulties of adjustment to the vagaries of nature, difficulties of adjustment to the complexities of human society, difficulties of doing what we want to do and of finding out what we want to find out — it is natural that some easy way should be sought. It is natural that the 'orderly procedure,' the 'series of steps,' should be passed by in favor of some simpler way. We shall now review briefly some of these simpler ways.

II

THE APPEAL TO AUTHORITY

Sources of Authority

1. *Universal need for guidance.* In the total number of a man's activities comparatively few will be brought consciously to his attention so he will not need to choose between them, much less ask any one's advice. The great majority of things that he does he will do because he knows or desires no other way. The *customs* of his folk and his own *habits* will make his decisions for him without his realizing that they are decisions. The clothes he wears, the gatherings he frequents, the food he eats, the shelter in which he lives, the language he speaks — these things are for the most part decided for him.

But some of the most important things that must be done cannot be decided by custom or habit; in times of crises these are frequently insufficient. In public life there are issues over which men clash, and the people call for a leader to solve their problems for them. One of the most pitiful things in the world is the prospect of a great people calling for a leader, some one to

solve their difficulties for them, some one to relieve them of responsibility, a Hercules to pull their carts out of the mire.

Each person, likewise, often feels the need of some one to show him the way, to help make his decisions for him. We read enviously of how Gideon was able to make assurance doubly sure through the simple means of a fleece and the dew and thus appeal to his highest Authority to aid him in the solution of the problem which was troubling him mightily.

Throughout the ages Man's difficulties, whether they have to do with his relationship to Nature or to his fellow-man, have been decided by an appeal to religious authority, with its recognition of the power of the unseen, or by an appeal to civil authority, with its recognition of the power of armed force. Even in the simplest unit of social organization, the family, the two powers were frequently recognized; the father was the religious and civil head. He was the priest and king. The absolutism of this authority is difficult to appreciate now in an age when both functions seem to have been so largely renounced. The stories of exposure of undesired children which come down to us from ancient times are in startling contrast to conditions as they exist

to-day. And while we can but admire the practice for its efficacy in solving the problem of the degenerate and deformed, and also because of the literature which has sprung up in the event of the exposed being of royal lineage and opportunely discovered and nourished by shepherds or wolves, nevertheless, few would care to return to the ancient custom and vest the power of life and death in the hands of the father of the family.

Where the unit of organization was the tribe, we discover a division of power. On the one hand was the tribal chieftain whose duty it was to lead the armed forces in battle against the enemies of the tribe, and in the periods between wars to act as a guide and a judge for his people. On the other hand was the tribal magician or medicine man whose function was to intercede between man and the unseen and incomprehensible forces of the universe, often to advise the chieftain himself as to the most auspicious time for the inception of a projected military undertaking. The relative power of these two branches differed among the different tribes, and at different periods within the same tribe.

2. *Religious authority.* The religious authority, *the man* who pointed out the way to follow by his familiarity with the unseen is a familiar

character in the mythology of any people. Whether his acts were directed by tradition, as was usually the case, or by his own whim, he was looked upon with awe because of his intimacy with mysterious forces. What schoolboy does not know of the 'heap big magic' of the medicine man of our American Indians? The Hebrew people with their Oriental contacts had their wise men and soothsayers who gradually became supplanted by the prophets as advisers to and at times commanders of the king. The Greeks and Romans with their Egyptian heritage, had their priests (and sometimes priestesses) to interpret the will of the gods for man, sometimes with the aid of an oracle, and sometimes by signs and portents that only they could properly interpret. Sometimes the truth was represented as being revealed directly to the person consulted. In the Celtic legend related by Scott in his *Lady of the Lake*, Brian the Hermit is consulted by the Highland Chieftain, and in order to give his augury must needs lie all night in a wild and lonely glen wrapped in the warm hide of a newly slain bull.

Only in the most primitive tribes, however, is the Man alone the revealer of the truth. Only where tradition is the only teacher does the medicine man have just such power. Where a

written language has grown up, there is gradually collected a body of writings often held as sacred to which recourse is to be had for guidance. These may be the codification of earlier usages, or they may be the writings or utterances of a great prophet and teacher, or they come from so distant a past that their origin is lost in the far obscurity of time. But whatever their source, such a group of writings in nearly every country has served to furnish guidance to the Man. The priest or prophet could quote from *the Book* and thus enhance his authority.

This book might be the code of Hammurabi or the Mosaic code. It might purport to be the writings of some prehistoric Asiatic prophet, or a later disciple, a Confucius or a Mohammed. The awe with which the Book can be looked upon as a solution of individual problems can be supremely illustrated in comparatively recent times, for reports are well authenticated of people who have opened the Bible at random and blindly pointed to the page. The verse thus selected by chance was expected to furnish the guidance sought.

Along with the authority of the Man and the Book, there developed the *Organization*. This was apt to be a group of priests or prophets whose

duty it was to interpret the Book. Sometimes, as in the case of the oracles of Greece and the Colleges of Augury in Rome, their sources of inspiration were more primitive. But as a body of doctrine came to be developed, the Organization came to have greater and greater power, so that, for instance, in Egypt and in India it was a separate social order with special privileges. Something of the sort came about in Medieval Europe with the extended power of the Roman Church and the appearance of priestly orders.

3. *Civil authority.* This same sequence — the Man, the Book, the Organization — is to be found, likewise, on the civil arm of the social order. The tribal chieftain profited by his position of power gained by physical strength or shrewdness of judgment and his ability to lead, and became the emperor or the sultan or the king or duke, commanding the subservience of the people and maintaining himself with pomp and splendor, particularly if he derived his heritage from Asiatic sources. According to his strength he had power over the religious authorities or did them abject obeisance. The fiction gained acceptance that the king could do no wrong by the simple logic that anything was right if he did it.

And the people were pleased to have some one

to take the responsibility for matters concerning which they were only periodically interested. This convenience spread to literature. In Shakespeare's plays, for example, even when the dénouement is inherent in the situation, Fate often has to have an august spokesman, as when Portia quotes the law to Shylock's discomfiture, and final disposal of the case is made by the Duke flanked by his magnificos.

As an aid or at times as a hindrance to the regal personage there was the Book, or the body of written law, possibly identical with the religious writings, possibly of separate origin, made up of decrees of former sovereigns perhaps codified. These were sometimes disregarded, and sometimes they had real significance like the law of the Medes and Persians.

Another source of the code of Law was the Organization, which appeared from time to time to hamper the free movements of the despot. These enactments had greater or less force among different peoples and at different times. Whether this organization was an oligarchy or a parliament, or whatever form it took, it was a source of appeal, a dispenser of truth, a regulator of lives and institutions. Its only rival was organized religion. So we have, on the one hand, organ-

ized religious authority, or the Church, and on the other, organized civil authority, or the State.

Education and Authority

In early times in nearly all countries authority furnished the aim and content of education. In China, the formal education of children began and often ended by a study of the writings of Confucius; in India by a study of the Vedas; in Palestine by a study of the Old Testament and other writings; in New England by a study of the Bible and later a primer based largely upon it. In these countries the religious rather than the civic influence was strong, though many of the books studied were largely secular in content. In Greece, Homer was read; in Ancient Rome, the Twelve Tables.

Not only was the subject-matter of education largely prescribed by such authority, but often the method as well, as illustrated by the words of advice in the book of Proverbs, or the minute directions as to schoolroom deportment contained in the writings of Confucius.

What the Book lacked in this respect was made up for by the Organization, sometimes religious as in India, Egypt, and medieval Europe; sometimes civil as in Persia, Sparta, and Rome. To-

day, we have both kinds of control as in the United States where a parochial system is in operation side by side with a state system.

Before going further, it should be noted that as civilization gradually became more complex, there came men, books, and organizations exercising authority in their particular domain, separate from and for the most part independent of the ecclesiastical and civil authority of which we have been speaking. Either Church or State was considered free to step in and regulate or control these at any time, though they have sometimes had to fight for this prerogative; but except in such cases, these other bodies were practically autonomous. Frequently they were considered parts of the larger and more inclusive organization like the military forces of a nation; some were more separate, like the applied arts, engineering, and the trades, or the fine arts.

Education, like these others, gradually developed a loosely organized body of knowledge and a more loosely organized body of workers. Limited by a paucity of appropriate material as furnished by the Book or the Organization of Church or State, individual workers, sometimes as an integral part of these organizations, sometimes working more independently, themselves

became the Men, themselves became the writers of the Books, themselves became the founders of the Organizations to carry on the work of education.

Sources of Professional Knowledge

1. *Custom.* And what was the source of this knowledge? Scientific investigation? No. One source was to be found in the adherence to custom. The things which had been done continued to be done. Anglo-Saxon agriculturists employed certain rather intricate charms and incantations with an overlay of their more recently acquired Christianity.[1] The potency of these charms we might now question. The American Indians told the early settlers of this continent to put a fish in each hill of corn they planted: this was less poetic than the Anglo-Saxon method, but it probably was of greater value though the Indians could not have told why. Similarly, in education, and with no knowledge of the why, as settlements grew into villages, and villages into cities with the westward movement of the population, the schools

[1] A number of these may be found in Cook and Tinker, *Select Translations from Old English Poetry* (Ginn & Co., 1902), and in Thorndike, Lynn, *History of Magic and Experimental Science* (The Macmillan Company, 1923).

which sprang up followed custom blindly, with their eight-year elementary school and their four-year high school.

Sometimes custom has proved to be an able teacher. Oftener the later introduction of considerable modifications brought marked improvement. The origins of the many commonly accepted customs are usually buried in antiquity, and even the source of such a comparatively recent thing as the 8–4 organization of public school grades is shrouded in uncertainty. Many factors are at work. If we may judge from such usages as are traceable, many of them may be derived from the speculations of some vigorous personality, speculations which were followed by conviction even though founded upon no rock stratum of fact, and which were perhaps constructed by him and put to use during his lifetime.

2. *Empirical Findings.* Such speculations or guesses based upon little more than a trial-and-error experience of one individual are often called empirical. We have seen illustrations of empirical agriculture. In the early days people used to talk about an empirical doctor, one whose skill lay chiefly in the things he had figured out for himself after a period of blundering and guess-work. There was little opportunity for one to

profit by the experience of another. Each did his own blundering, made his own trials, and the errors were taken care of by the undertaker. The medical school, with its complete equipment both in apparatus and in knowledge based on careful scientific work over long periods of years and derived from the efforts of investigators the world over, presents an interesting contrast to the empirical doctor of a few generations ago.

It comes as a shock to realize that a great deal of what goes on under the name of education shows a greater likeness to the work of the empirical doctor than to the work of the medical school. Teachers discover their own ways to meet situations after months and even years of blundering, and then perhaps they have discovered only mediocre ways, and this is what is so much prized under the glamor of the word 'Experience.' Young men who act as principals of schools are left to figure things out for themselves and mimic the ways of the principals they knew, and are often ignorant of the accumulated experience of others that is being made available for them. The empirical educator is fast becoming the museum relic that the empirical doctor has become. Perhaps the reason this did not happen sooner is that though his trials are

no less blind, his errors are not so striking. Instead of physical death, they result only in such things as waste of time and money, dreary useless monotony, petty unpleasantness or unnecessary disciplinary situations, in dislike of pupils for intellectual activities, and often in hatred and ridicule of the whole process including the people operating it.

The one hopeful thing about this type of empirical professionalism was that it had a tendency to break with authority. If a new situation arose, a new way to deal with it had to be devised; and whereas the time-sanctioned authoritative regulations might have handled the situation more adequately, there was always a chance that occasionally something better might be devised.

3. *Speculation.* If we shift the emphasis in the question of the solution of problems from meeting an immediate difficulty which has to be handled at once, like a baffling disease, or an insurrection in the school, to deliberating more at leisure in the quest for general truths or principles which might later be applied to such acute situations should they arise, we find ourselves in the hopeful period of speculation which oftentimes preceded vigorous advances in the various fields of knowledge.

Descartes is usually considered the arch-modernist when it comes to distrusting the authoritative dicta of the past. He seems to be the supreme doubter of all time among the intellectuals. Schooled in Aristotelian logic, he knew the inexorable nature of its processes, which, however, often led to conclusions that became increasingly untenable as scientific activity progressed, and he came to realize that the weakness was in the premises. Grant certain premises and certain conclusions are irrefutable. The medieval mind was credulous: it had not trained itself to question premises; it had been schooled to accept them from whatsoever authority was dominant. It had not learned to distinguish facts from thought about facts; that is, doctrines.

Descartes saw so many fine structures reared on mountains of ice that crumbled as soon as the warm breath of science melted the foundations, that he questioned every construction of thought. He suspected every woodpile of secreting the African he had found lurking in so many. He had the attitude that is so valuable nowadays when listening to the plausible selling talk of an impassioned salesman, that there is a 'catch' somewhere. He went so far as to distrust his own

senses and to wonder if the people who passed him in the street were really there, were really people, or if his idea that they were there was also error. Such a reaction against authority was bound to have a wholesome effect in that among other things it would call men's attention to the distinction between what they were pleased to call facts, and what were mental constructions concerning the facts.

One sort of speculation which properly belongs in the pre-scientific period, though it is all too prevalent even to-day, is *rationalization.* The technical meaning of this term has been made common property by Robinson in his *Mind in the Making.* When one holds to an opinion derived from no clearly recognized source, usually from one's father, or community or church or party, etc., and then seeks to justify that opinion or prejudice by some form of reasoning, maintaining that the opinion is held because it is the result of such reasoning, the process is called rationalization. A man may say that he belongs to a certain religious denomination because he agrees with its tenets, and that he votes the Republican ticket because he believes in the protective tariff; whereas he belongs to the denomination, votes the Republican ticket and believes in

the protective tariff because his father did before him. He had not broken away from the force of authority. Rationalization is finding a plausible reason for the belief that is in us, and there are some cynics who go so far as to say that the whole history of philosophy is nothing more than an intricate framework of rationalization reared to support preconceived opinions.

In direct opposition to rationalization is the true attitude of the man of science (the attitude may be held by philosophers as well) which, instead of holding to an opinion through thick and thin, supporting it by one argument after another, cautiously seeks to find out the truth, and is content when he has found it, whether it turns out to be in accord with his original opinion in the matter or not. Louis Pasteur exhibited that attitude, and he was perhaps as nearly an incarnation of the scientific spirit as the world will ever see. When the reverberations of his painstaking research disproving spontaneous generation had attracted the attention not only of scientists but of people generally and had seemed to destroy the foundation of their pet theories derived they knew not whence, he spoke to them in a language they could hardly understand. Instead of taking the attitude of one who would support a philo-

sophical theory he said: "It is a question of fact; when I took it up I was as ready to be convinced by experiments that spontaneous generation exists as I am now persuaded that those who now believe it are blindfolded."[1]

Speculation may be said to hold the middle ground between authority and science as a method for deriving answers to our questions and establishing principles. There is one kind of speculation which approaches very close to the spirit of science in that the opinions derived from it come from no hidden sources and need no rationalization to give them credence. For the attitude of one who uses this method is in one respect the attitude of the scientist: he will accept the results of the process and follow where it leads.

'Armchair' inquiry is the name which was given in derision by the psychologists to this kind of speculation, for, owing to the nature of their subject-matter, they have numbered many employing it in their ranks. Clearly the advantage of throwing off the incubus of authority and marching forth to whatever places the mind discloses, unburdened by any preconceived no-

[1] Vallery-Radot: *The Life of Pasteur* (Doubleday, Page & Co., 1923), p. 112.

tions is a real one. But as a final solution to problems of the mind, even, it has certain definite disadvantages which tend to be corrected by the more rigid method of science. Its conclusions are often true, but quite as often wide of the mark, and are not dependable for they are drawn from too few cases, and are necessarily influenced to a large degree by the experiences of the man himself, the progress of knowledge, and social and economic structures and the ideas prevalent at the time in which he lived.

And yet, if he is a forceful personality, or a vigorous writer, even though his conclusions are derived from no closer contact with reality than an armchair comfortably placed before a cheerful log fire, he will himself become an authority, be bowed down to and followed by his generation and by generations to come until a scientific attack on the problems with which he dealt begins the work of separating the true from the false. Meanwhile his influence has not been all harmful, for he has attracted attention to the problem, his solutions may be well along the way to truth, and he has perhaps aroused the ardor of more careful investigators.

Almost any name in the history of psychology previous to the time of Wundt and of James

would afford an abundance of illustrative material. In the field of education so closely related to it, perhaps the work of Herbart might be taken as an example. There is no evidence to show that this man whose life was spent as a college professor based his educational pronouncements on anything more than his own armchair speculation. Yet they were put into practice, and when they reached this country they created a furor, and his words were on all lips. Correlation, concentration, apperception, five formal steps of the recitation — the 1890's accepted these as the law and the gospel, and when the furor calmed down in the 1900's it was found that no small amount of good had been done, and that though much should be discarded much could be retained, and practice and experimentation alone could determine which was which.

4. *Scientific Inquiry.* But custom, empirical findings, and speculation though they accomplished much, lacked the adequacy which seemed to be proffered by the example of the use of the scientific method as employed by the natural sciences. Before considering how this method is applicable to other fields of professional knowledge, let us turn aside to examine more carefully what the scientific method is.

III

SCIENTIFIC PROCEDURE: PROBLEM-SOLVING

The Emergence of the Scientific Method

ONE of the most familiar and dramatic illustrations of the use of the scientific method as over against the appeal to authority is found in the classic story of Galileo and his experimentation with falling bodies. When not long ago I made a pilgrimage to Pisa and climbed that seemingly endless spiral staircase up the famous Leaning Tower, I could but think of how that man of long ago had laboriously climbed these same three hundred well-worn steps time after time because he had an idea. And in order to verify that idea, he employed this laborious method, preferring it to authority, preferring it to consulting Man, Book, or Organization for his answer. And because he did this thing, the world gained a new truth. No longer could any but the ignorant assume that the heavier a body is the faster it falls, because he had demonstrated that all bodies fall at the same rate, no matter how much they weigh, barring the influence of atmospheric resistance. He knew because he had resorted to the

ridiculously simple device of dropping weights from this convenient height and timing their fall. And then the other factor, atmospheric resistance, could be considered by itself. For when, later, a feather and a coin were placed in a glass tube, and the air was exhausted from it, they fell together when the tube was reversed. They behaved according to the prediction. The hypothesis was verified. If any one did not believe, he could repeat the experiments, and he would get the same results. The Method had been established.

When Copernicus discovered that men in ancient times had considered it likely that the earth was not the stationary center of the universe as the majority in their pride supposed, but that it was possibly a comparatively small spherical body whirling on its own axis and moving around the sun, he set to work humbly to study the problem. After years of employment of the Method, clumsy and full of error as his work was, he arrived at conclusions that to the many seemed ridiculous and to the church seemed dangerous. Galileo, following the work of Copernicus, following his method, convinced himself of the truth of his conclusions and became a staunch supporter of the Copernican as

over against the more flattering Ptolemaic Theory. Judging by its action in the matter, the Organization considered such deviation from the usual as dangerous and subversive of its doctrines. The Inquisition was on, and poor Galileo was proclaimed a heretic and had the choice of recanting or suffering the consequences. He decided on the former course. Probably he considered that what he said or did not say would have very little influence on the actual movement of the heavenly bodies; and he was no doubt scientist enough to believe that in this particular at least, the Organization would have no more effect. So on his knees in Rome this old man, now past seventy, according to the proper and wordy form completely and abjectly recanted. Whether or not the story is true that upon rising he muttered, "It does move, though," [1] the situation at least showed that the Organization was still on top, that Authority was master.

And the story is not finished even to-day. The Organization may or may not be ecclesiastical, and the method may or may not be applied to the physical sciences alone. But if the findings by the use of the Method are contrary to the well established teachings of the Authority, be it

[1] *Eppur si muove.*

Man, Book, or Organization, there is certain to be conflict; for those of the Organization seem never able to learn that they do not have control over the uniformities of nature, which are gradually and painstakingly being discovered and called laws — that they are operative any way, and no abjuration, or punishment of the finder of them, and no amount of invective will change them in the least.

Of course, Galileo was not the first to swear allegiance to the Method rather than to the Organization in the matter of the nature of the universe. The beginnings run far back into antiquity. I would not doubt that the first man to think of digging canals and constructing reservoirs in Old Egypt was buried alive in the sand because he proposed to hamper the free movements of Father Nile. The first scientists of Greece, the cosmic philosophers, whose interesting speculations as to the ultimate nature of things have come down to us, were as truly free-thinking individuals as Galileo, though their Method needed later elaboration. Their spirit was the spirit of science.

The physical sciences emerged comparatively early from the realm of speculative philosophy, and were hastened by the discovery of the tele-

scope and other mechanical devices. The biological sciences broke away from fantastic speculation and authoritative pronouncements still later, being given a tremendous impetus by the invention of the microscope. Nearly all the conflicts of the physical sciences with preëstablished authority have died down. Those with the biological sciences even now flame up occasionally so as to attract notice, as for example in the difficulties that certain men are having with evolution. These men are just the descendants, intellectually of the inquisitors of Galileo, who could not reconcile the Copernican theory with what they had been taught.

The social sciences are even now beginning to unroll; and while some conflicts have already appeared over the edge of the horizon, the conflicts of the social sciences with Authority are for the most part in the future. Findings are too tentative, as yet; they are not widely known or fully understood; their implications are not sufficiently appreciated. We of the present can, therefore, watch these groups of studies like sociology, geography, civics, psychology (though here the relationship to the biological sciences is perhaps closer), and education slowly beginning to emerge from the chrysalis.

Scientific Results and Scientific Inquiry

To those whose sole acquaintance with scientific procedure comes through reading popular articles, or even to those who are familiar only with the scientific journals and the results there presented in their most concise form, the scientific method must necessarily seem a most exact process with no false steps, with everything in its place and leading directly to the inevitable conclusion. How different this is from the fact is most easily ascertained simply by reading the story of the discovery of some truth or law by a Kepler or a Newton or a Pasteur.

It is very like the child learning to do long division. "How do you know how many times the divisor is contained in the first digits of the dividend?" he asks, and is surprised to find that he has to guess. He was expecting some hard-and-fast rule, and even the teacher has to try two or three times occasionally, just as he does. True, there are certain little schemes he can employ to help. He can use just the first digit in the divisor, and that may give him a hint, but he can't be sure. He can't know until he tries it out.

Little do the uninitiated realize the pains-

taking trying-out process that precedes the discovery and verification even of the most minute discoveries of science. How much more, then, the major discoveries! They do not come about by a "stroke of genius" except as the genius is able to devise innumerable situations to test out the trials which he makes.

The lecture from which the following extract [1] is taken was delivered by Pasteur in 1864. It took him only about an hour to repeat some of his experiments and explain his conclusions in a most vivid manner in the large, crowded lecture room of the Sorbonne. How simple and clear are his statements:

> I place a portion of that infusion into a flask with a long neck (like this one). Suppose I boil the liquid and leave it to cool. After a few days, mouldiness or animalculæ will develop in the liquid. By boiling, I destroyed any germs contained in the liquid or against the glass; but that infusion being again in contact with air, it becomes altered, as all infusions do. Now suppose I repeat this experiment, but that, before boiling the liquid, I draw (by means of an enameller's lamp) the neck of the flask into a point, leaving, however, its extremity open. This being

[1] Vallery-Radot: *The Life of Pasteur*, p. 108. (Doubleday, Page & Co., 1923.) Quoted by arrangement with the publishers.

done, I boil the liquid in the flask, and leave it to cool. Now the liquid of this second flask will remain pure not only two days, a month, a year, but three or four years — for the experiment I am telling you about is already four years old, and the liquid remains as limpid as distilled water. What difference is there, then, between those two vases? They contain the same liquid, they both contain air, both are open. Why does one decay and the other remain pure? The only difference between them is this: in the first case, the dusts suspended in air and their germs can fall into the neck of the flask and arrive into contact with the liquid, where they find appropriate food and develop; thence microscopic beings. In the second flask, on the contrary, it is impossible, or at least extremely difficult, unless it is violently shaken, that dusts suspended in air should enter the vase; they fall on its curved neck. When air goes in and out of the vase through diffusions or variations of temperature, the latter never being sudden, the air comes in slowly enough to drop the dusts and germs that it carries at the opening of the neck or in the first curves.

This experiment is full of instruction; for this must be noted, that everything in air save its dusts can easily enter the vase and come into contact with the liquid. Imagine what you choose in the air — electricity, magnetism, ozone, unknown forces even, all can reach the infusion. Only one thing cannot enter easily, and that is dust, suspended in air. And the proof of this is that if I shake the vase violently

two or three times, in a few days it contains animalculæ or mouldiness. Why? Because air has come in violently enough to carry dust with it. Never will the doctrine of spontaneous generation recover from the mortal blow of this simple experiment.

But what preceded this simple experiment, what was Pasteur's preparation for this lecture? Six years of the most constant and painstaking labor. Although the cruder belief that rats could be created out of cheese and old rags had largely gone into the discard, the ghost of spontaneous generation had begun to walk with the discovery, by means of the microscope, of a world swarming with life of which no one had dreamed, and so teeming with minute organisms that spontaneous generation seemed the only answer as to their origin. Certain scientific men of the period went so far as to claim that they could prove that these microscopic animals and plants could be generated without any connection with other germs.

The story of this controversy is as dramatic and as full of human interest as any fiction. In the course of his experimentation, Pasteur invented various devices to keep out the air and the contents of the air from the liquids in his flasks. He tried various kinds of flasks inventing many

new shapes; he tried boiling different liquids in these different flasks for different periods of time, all the while examining with his microscope to find the influence of the different situations. To discover if air at different places contains varying quantities of these microscopic creatures, he carried especially prepared flasks containing the same liquid to different places, city streets, country roads, cellars, even high up in the Alps. Many times in each of these different places he broke the neck of a flask allowing the air to rush in, then skilfully sealed it again and took them all back to his laboratory for careful examination. A few minutes to tell; nearly six years of painstaking effort to discover and prove.

And it is the same story for every discovery. In the field of psychology Ebbinghaus in the course of his experimentation memorized 21,312 nonsense syllables besides many practice series before he gave us the laws of learning and forgetting. Little idea can be gained from reading the conclusions of a scientific labor, of the path followed and the unsuccessful trials made by the experimenter before he is able to reach them. This long process of reflective thinking is an integral part of the scientific method and will now be considered in detail.

Problem-Solving

1. *Seeing problems.* In the first place there must be some starting point. It may not at first have the definiteness of a problem; it may be just a feeling of insufficiency in a certain situation, a lack of contentment, a feeling of dissatisfaction in the face of certain conditions or pronouncements, an attitude of questioning or doubt, perhaps in regard to certain generally accepted ideas. The idea of spontaneous generation, for example, in the time of Pasteur, was gaining credence in view of the swarming billions of creatures revealed by the microscope. Where did they come from? Here was the difficulty. To Pasteur, the answer that they came into being spontaneously without parent cells was a dubious one. Here was his difficulty, his problem; so he set about the task of finding the solution. Copernicus was dissatisfied with the accepted explanation of the movement of the heavenly bodies, and getting a different idea from certain ancient writings, he set to work on his problem. Illustrations are by no means confined to the physical sciences. Many of us have certain half-formed opinions concerning superior children — that if they are particularly brilliant in one direction they are

deficient in others — perhaps in the social graces or in healthy physical development, or that they are not thus deficient, but instead that they are superior in practically all respects. Here is a real difficulty, and Terman has decided to resolve it by making a study of approximately one thousand superior children, taking careful measures in every possible fashion. The results of his investigation will not be complete until these children have grown and demonstrated by their lives whether their early promise is to be fulfilled.

The influence of heredity, the dynamic value of instinct and habit, the transfer value of different subjects and different methods of instruction, the place of vocational advisement and training in the schools — these are just a few samples selected at random from the many problems that confront educators to-day, problems which are crying for a solution, problems which cannot be satisfactorily answered by any blind following of custom, by any appeal to authority, or by any resort to individual opinion no matter how well thought out it may be. The slow, painstaking method of science is the only direction in which we may look for any answer in which to place any real confidence.

Individuals differ greatly in their ability to *see*

problems. Oftentimes students finish college and go on to graduate school before they discover that they need to do some original research before they will be awarded a graduate degree. So they confer with some member of the graduate faculty and ask him for a problem to work on; they can't seem to think of any. Can't think of any, and the world fairly bursting with them!

A friend of mine, a young professor of philosophy, has occasionally expressed considerable dismay at the lack of ability on the part of his students to see problems. They are so content with everything. The world is all right as it is, especially if they succeed in having a good time. Of the problems crying for solution in the state and nation, in the social structure of our twentieth century,— of these they are blissfully unaware. And he wonders if after all it is his duty to call their attention to these problems. If he does they either evince little interest, or at most are but momentarily disturbed, and they seem quite unable to do anything about it, quite incapable of closing with any one of them and exacting a solution. Should he call the attention of his students to these problems? That in itself is a problem.

It is at this point that the problem-project

method of which we have heard so much of late has an opportunity to be of real service. Perhaps it isn't the fault of these students that life presents no real difficulties, that they are unable to see problems. Little opportunity has been afforded them. They have lived in the era of the rule of authority, even though it is the twentieth century. Their problems as well as the technique of solving them have been furnished ready-made. They have always been told what to do. Their parents first and then their teachers joined the authoritative band. "Take the next ten pages; do the next twenty examples; translate the next fifty lines." Obediently they buckle down and do as much of what they are told as they consider necessary. Why should they discover problems for themselves? They have never been taught to. As well expect the boy who has spent all his life in the city to see a squirrel peeking out from the other side of a tree trunk with the quickness of perception of the boy who has lived in the woods all his life. The scientific method is a method of solving problems, and the first prerequisite is to see the problem.

The felt difficulty may be due to a complex of situations, and a little time spent in *analysis* will usually unearth a whole nest of problems, each one

of which may require a different method of attack.

It is in such a situation as this that the beginning teacher often finds himself. He may have had excellent preliminary training including practice teaching. But when he gets away from the kindly influence of his teachers and supervisors and into a different, perhaps inferior school system, he is quite apt to turn against the whole situation and become discouraged at his inability to make good at his new job. He has difficulties enough; the situation is full of them. If he is wise, he will analyze it to see what the different problems are, such as getting on with his immediate superior, bringing about the purchase of new equipment, discovering which of his pupils are at the center of the trouble-making; what is the best method of handling them; of gaining the good will of his pupils, of his colleagues, and of the people in his community, and at the same time standing by the things which he considers best.

People often make the mistake of applying one remedy to a complex of disorders. We frequently hear persons pretentiously announce what the world needs, when they have only the shadiest idea of the complexity of the problems they would solve so easily. The beginner in scientific

investigations is apt to attempt the solution of too big a difficulty, and be impatient with the seeming pettiness with which he is brought face to face after he selects one of the problems into which he has analyzed his total situation.

2. *Discovery of the solution.* But it is one thing to see difficulties and quite another to think of solutions. Whatever care is used in analyzing the situation, whatever thought is used in discovering and isolating the problem, at least one solution must offer itself. How seldom one solution is sufficient has already been intimated. Many solutions will usually have to present themselves before the correct one is discovered.

Just as people differ greatly in their ability to see problems, so too, do they differ in the rapidity and ease with which suggestions come to them. It is probably true that this ability can be improved by training, but to how great an extent is unknown. Certainly those scientists who have made contributions of major importance had the ability to a very marked degree. Sir Francis Galton has left us a most illuminating account of his thought processes as he had observed them, when he was confronted by a problem: [1]

[1] Galton, F.: *Inquiries into Human Faculty and its Development* (The Macmillan Company, 1883), p. 203.

When I am engaged in trying to think anything out, the process of doing so appears to me to be this: The ideas that lie at any moment within my full consciousness seem to attract of their own accord the most appropriate of a number of other ideas that are lying close at hand, but imperfectly within the range of my consciousness. There seems to be a presence chamber in my mind where full consciousness holds court, and where two or three ideas are at the same time in audience, and an antechamber full of more or less allied ideas, which is situated just beyond the full ken of consciousness. Out of this antechamber the ideas most nearly allied to those in the presence chamber appear to be summoned in a mechanically logical way, and to have their turn of audience.

The successful progress of thought appears to depend, first, on a large attendance in the antechamber; secondly, on the presence there of no ideas except such as are strictly germane to the topic under consideration; thirdly, on the justness of the logical mechanism that issues the summons. The thronging of the antechamber is, I am convinced, altogether beyond my control; if the ideas do not appear, I cannot create them nor compel them to come.

Besides seeing problems and waiting for solutions to suggest themselves, attention must be given to the *relative value* of the solutions suggested. They must be examined carefully with

a view to their acceptability. The landlord who assures his tenant that the explosions of the gas heater are due to the ashes on the cellar floor, and that the water dropping from the kitchen ceiling when it rains is due to the steam produced in cooking has greater facility in making suggestions than he has ability to evaluate the suggestions which he makes.

A graduate student at one time discovered a difference in the heart rate of different individuals when considerable pressure was exerted on their closed eyes. He decided that this was a gauge of musical ability and induced nearly all the members of one of the city bands as well as his fellow graduate students to allow him to push in their eyeballs to prove his thesis. He certainly hit upon a remarkably ingenious solution, but one which few would have considered it necessary to try out. Sir Francis Galton, according to his account, did not experiment upon the helpless universe in connection with every suggestion that occurred to him. Instead, he viewed the suggestions a few at a time, accepting some as probable and worth working on, rejecting others as unsatisfactory. The necessity for doing this is obvious. If every suggestion were put to the test, so much time would be consumed in fruit-

less endeavor that little work of real value could be done. True, the most likely solutions may prove futile, and then the less probable ones may be tested, for often the answer lies in the most unexpected quarter.

But how can one know which are the most likely solutions? No satisfactory answer can be given to this question. Native intelligence, whatever that may be, probably has a great deal to do with it, as does particular knowledge, special training, and experience. The landlord above referred to was probably incapacitated for a proper evaluation of his suggestions not only by his desire to avoid additional expenditures but also by his lack of intelligence. The graduate student who sought the seat of musical talent in an eye-heart reflex was perhaps lacking in a thorough knowledge of physiology. One reason that successful investigators are successful is that with their training and experience, they are able to render expert opinion on matters which another might spend futile weeks in investigating. Their minds are so in tune with their subject-matter that at once a proposed solution will be deemed reasonable or ridiculous. If it is reasonable or acceptable tentatively, it will need still further consideration. Its implications will have

to be considered and tested. In other words, we have an hypothesis.

In his famous speech on Evolution, W. J. Bryan makes a great deal of the point that the doctrine which he so denounces is called the evolutionary hypothesis, and that an hypothesis is defined in the dictionary as a 'guess.' Then, with a fine disregard for logic, he sets forth on a trail of fiery invective against the man who would put his faith in a 'mere guess.' From what has already been said, it is clear that an hypothesis must be more than a mere guess, and just how much more it is worth while now to consider in detail.

Degrees of Certainty

1. *The hypothesis.* The hypothesis is a first step beyond random suggestions in the direction of scientific truth. It is the reasonable answer which requires testing, and which may prove false or true. For the moment it is assumed to be true, and the investigator sets out to consider what would happen in consequence. If the consequences of this assumption that the hypothesis is true are not in accord with the established facts, it must necessarily be rejected as false. Kepler made nineteen hypotheses concerning the form

of the orbits of the planets, each one of which he had to abandon after months of mathematical calculation, before he tested the twentieth hypothesis — that is, that these orbits are elliptical — when he found that it alone was in accord with the facts.

The hypothesis is not a proposition the truth of which must be supported through thick and thin in order to convince people and win a debate or a political contest. It is rather a temporary working principle which the scientist is willing to relinquish whenever the facts favor some other hypothesis which, in turn, may or may not prove tenable. Thus the path of the scientific investigator is strewn with the bodies of slain hypotheses.

The good hypothesis *must be in agreement with the facts*, but this general statement may be elaborated so as to present three distinct qualifications:

First: it must allow the application of deductive reasoning and the inference of consequences capable of comparison with the results of observation. That is, we should be able to say, 'If this tentative hypothesis is true, such and such things will follow.' These things must be of such a nature that we can observe whether or

not they actually do follow. Thus when Pasteur formulated the hypothesis that micro-organisms spring from other organisms like themselves, and that these are transmitted with the dust of the air, it was easy to infer the possibility of studying air without dust, which would conceivably render impossible the continuance of these organisms.

Conversely, we must be able to say 'If this hypothesis is *not* true, such and such things will follow.' That is, to be a good hypothesis it must be of such a nature that its invalidity under particular circumstances is conceivable. The consequences of such a condition can then be inferred with a view to finding out if they maintain. Pasteur could say: "If my hypothesis is not true, bacteria will appear in the water from which the dust of the air (and hence other bacteria) has been excluded." But they did not appear under those conditions.

An illustration of a condition in which this qualification is not fulfilled may be taken from the realm of faith-healing. If a cure follows, faith is responsible. If a cure does not follow, there is not enough faith. In either case, the patient's belief in the therapeutic power of faith is unshaken. Indeed since it cannot be dis-

proved (or proved either, for that matter) he is all the more certain of its validity.

The second qualification of the good hypothesis is that the consequences inferred must agree with the observable facts. Here again the hypothesis of Pasteur stood the test. The consequence inferred was that water free from bacilli would remain free from them if not exposed to the dust of the air. The observed fact, as reported above, was that the water in the curved-necked flask into which the dust of the air could not enter under normal conditions, remained free from bacilli for the four years that the test was being conducted. Galileo, from his investigations into the laws of falling bodies, formulated the hypothesis that the difference in the rate of fall was due not to their weight but to atmospheric resistance. If this were removed, all would fall together. This was subsequently demonstrated with the feather and coin in the vacuum as previously described.

The third qualification of the good hypothesis is that it must not conflict with any law of nature which we hold to be true. For example, it would be a foolhardy experimenter who would set out to prove that the fewer the repetitions of a selection the longer it can be retained in the memory. This is manifestly so at variance with the Law of

Frequency or Exercise that it is discarded at once. Occasionally a Jacques Loeb or an Einstein arises who puts forward hypotheses which question certain conclusions of a Pasteur or a Newton. But they do it wittingly, just as Copernicus put forward an hypothesis at variance with the commonly accepted theory of his day. Exceptions to this qualification are clearly necessary, but they are only exceptions.

2. *The theory.* If all the consequences possible to infer do agree with the facts of observation, the hypothesis becomes either a theory or a law. The theory is a statement of truth as it is believed to exist on the basis of all the facts that are at hand. It is, then, farther along the path to certainty than an hypothesis. It carries the idea of a wider acceptance than the hypothesis. It is a mental construction to account for facts as they exist. It has been tested by many investigators, and it seems to account for more of the facts and account for them better than other hypotheses. We have certain phenomena; if certain things were true we should have these phenomena. Therefore, let us act as if these certain things are true and so explain our phenomena.

The theory of spontaneous generation was put

forward to account for the swarming micro-organisms. If these creatures came into being spontaneously, we should have such conditions as we find, argued those supporting the theory. They could not imagine parenthood operating on such an enormous scale as would be necessary to produce so many billions of creatures in so short a time. Their theory seemed to be necessary to account for the facts. When Pasteur took a flask of water with an infusion of these creatures in it, killed them all by boiling, and then sealed up the flask so that no air could get at the water; and when he showed that in this flask no bacilli were generated, while they were generated in the same kind of water, boiled in the same way but *not* shut off from the air, he destroyed the older theory.

The electronic theory is generally accepted by physicists and chemists at the present time. No one has seen an electron. But if there were electrons, matter would behave as it does. Let us therefore assume their existence. On this basis, it is possible to account for static electricity, current electricity, magnetism, the radiations of light, X-rays, chemical action, the atoms of matter and their peculiar properties, and the phenomena of radio activity.[1] But still we have

[1] Duncan, R. K.: *The New Knowledge* (Barnes, 1906), p. 187.

only a theory for though it accounts for all these things, still it does not account for certain other phenomena of the universe such as positive electricity, gravitation, or life. That theory is most acceptable which most simply accounts for the greatest number of phenomena.

An hypothesis which has recently acquired sufficient prestige to become a theory is that of organic evolution. All the evidence that can be brought to bear tends to substantiate it. "But it has not been proved," shouts the narrow religionist. "Every biologist will tell you that it has not been proved." And of course this is true. It has not been proved. Furthermore, at the present time there seems no possibility of its ever being completely demonstrated. So it is with the Copernican Theory which troubled the narrow religionists of five hundred years ago. It has not been proved, and probably never can be. But all the phenomena of the solar system as they have been observed seem to need just this explanation, and so it is regarded as true. The older Ptolemaic theory which it supplanted was not able to account for all the phenomena.

From what has been said, it is clear that there is no sharp line that can be drawn between an hypothesis and a theory. This is particularly

true in the newer fields of scientific investigation as for example in psychology and education. Freud concocts an amazing hypothesis concerning dreams and their symbolic interpretation, and it is called a theory. Other hypotheses concerning the influence of glands, the nature and origin of consciousness, the subconscious, the instincts, and the like, have been published abroad as if they were well-substantiated theories. To the extent that they are used as a working basis for further inquiry, they are hypotheses and useful. To the extent that they are considered as the best interpretation of the phenomena, they may be called theories, but as such they are dangerous because they are really only daring surmises, and because assumptions based upon them are more than likely to be untrue and to lead to serious error in application, if not to positive harm.

Of course, what is at one time a generally accepted theory may at a later time due to an advance of knowledge, become quite untenable. Just as the path of the scientific investigator is strewn with the bodies of rejected hypotheses, so the path of science is strewn with the bodies of discredited theories. Yet a theory should be capable of wider acceptance than the hypothesis

and the loose usage which makes them all but identical is greatly to be deplored.

The theory that the brain is the seat of consciousness, Thorndike's theory of feeling, or of identical elements in the transfer of training, the James-Lange theory of the emotions, the constancy of the I.Q. — these are formulations which have sufficient evidence in support of them to be called theories, even though they may be amended, otherwise corrected, or even eventually discredited.

3. *The law.* Some hypotheses become theories; some become laws. Whether they pass through the one stage into the other is immaterial. The law represents the final stage in scientific certainty. *It is a statement of the uniform behavior of natural phenomena.* It is the statement of a relationship that is always found. All predictions made on the basis of it invariably come out as expected. The law of gravity states that the attraction between bodies varies directly as their masses, and inversely as the square of the distance between them. Here is an out-and-out statement of the relationship between bodies, arrived at by a long, painstaking process, but statable in definite fashion and capable of verification by any expert. It has always been found

to be reliable, and it is this continual reliability of a theory which constitutes its truth. The same may be said of Mendel's law, of the law of forgetting as expressed by the curve, of the law of exercise. These are statements of uniformity which have been found to be universally true. Given certain conditions, other conditions invariably follow. The greater the bodies, the greater their attraction for each other; the longer the lapse of time, the greater the amount that is forgotten; the more practice, the stronger, more precise and more smooth-running the reaction.

Natural and Civil Law

Confusion often arises as to the difference between natural and civil law. It is unfortunate that the two meanings should employ the same word; for there is even more difference between them than there is between the meanings of the word 'guess,' which Mr. Bryan confused. A natural law is a statement of uniformity existing in the universe; a civil law is a man-made rule of conduct, administered by men. It can be disregarded by those who are willing to run the chance of being found out and of suffering punishment according to the statement of penalty in the law. A natural law is discovered after care-

ful, painstaking effort; a civil law is formulated to suit the desires of law-makers and their constituents.

The only sense in which the two are similar is in the supposition that a Creator made rules to be observed by all creatures as well as by all inanimate objects. The idea of wrongdoing can also be injected into this meaning, as when it is used in connection with the so-called laws of health. If a person eats too much, he is punished by an attack of the gout. More broadly, if he dares to disregard the law of gravity and jumps off a cliff, he is punished by being dashed to pieces. He is punished in the same way if he falls asleep and rolls off. It is difficult to see why such severe punishment should be meted out to one who seems to have done no wrong. This is particularly true in the case of the less obvious law such as those relating to disease, in which man is made to discover the laws before he can 'obey' them. When we carry this idea of punishment of inanimate things like stones crushed under the weight of a glacier, the idea becomes still more fanciful. No, a civil law is a man-made rule of conduct; a natural law is an exact statement of an existing uniformity. It is merely a formula and governs nothing.

Induction and Deduction

Deduction without induction is the method of reasoning from authority; it is the process of drawing conclusions from principles which one does not question. These principles or premises may have their source in a dim past, they may be generally accepted notions of the day, or they may be scientific laws — it matters not a whit. It is said of certain systems of theology, 'Grant the premises and the conclusions are inescapable.' And rather startling conclusions they often are.

The medieval mind, as we have seen, was peculiarly willing to accept almost any statement as a premise and build the most elaborate superstructure of reasoning upon it. Copernicus, daring innovator that he was in his own day, was constantly dependent upon such absurd principles for his reasoning as the following: The sphere is the most perfect figure, therefore the universe is spherical. It is only given to wholes to move circularly, while it is the nature of parts separate from their wholes to move in straight lines; hence a body falls to the earth.

The basis of deductive logic is the syllogism; for example,

All men are mortal,
Socrates is a man,
Therefore Socrates is mortal.

The deductive logicians were content to consider various ways in which the minor premise and conclusion might or might not follow from the first statement or major premise. In other words, they were concerned with the principles of proof or demonstration. They were not particularly interested in the origin of the major premise, the inclusive assumption upon which their reasoning was based.

Scientific reasoning must needs use the methods of deductive logic, but it *first questions the major premise which it establishes inductively* by trying it out in a sufficient number of cases to be reasonably sure of its truth. Let us use a simple illustration. If I should say, "Guess what color this leaf is that I found," you might say, "Green, of course." Your reasoning could be outlined in full as follows:

All leaves are green,
This is a leaf,
Therefore this is green.

But the scientist is not satisfied with that first assumption, the statement contained in the

major premise. He therefore proceeds inductively. He examines leaf after leaf, he examines hundreds and thousands of them. In his search he finds one that is yellow and one that is red. So the conclusion is false because the premise is false, though the reasoning is faultless.

The search for a generalization, an hypothesis consists of nothing more than an analysis of case after case to see if every one can be included in some general formula. Hence it is said that inductive reasoning moves from particulars to the general, while deductive reasoning moves from the general, the hypothesis, to the particulars; that is, the implications that may be drawn on the basis of the known relations. Induction establishes the major premise; deduction draws the possible conclusions from it for the sake of further observation and testing.

Clearly, in any scientific research, it is impossible to keep the two processes separate, and it is unnecessary to do so. Every inference drawn from every suggestion that comes to mind in the face of a problem is deduction; every careful search into the phenomena of nature suggesting some uniformity is induction; every bit of reasoning immediately based on any such suspected uniformity is deduction. The contribu-

tion of the experimental sciences in this particular is the development of rules and principles of inductive procedure, thus giving certainty to the premises from which deduction starts.

Aristotle, in his master work, *The Organon*, or *Instrument*, set forth in detail for all time the principles and practice of deduction or proof. Francis Bacon, a contemporary of Descartes and Queen Elizabeth, in his *Novum Organum*, or *New Instrument*, set forth the principles of induction with its careful, accurate observation of phenomena and avoidance of assumptions, which he calls idols, whether they be common modes of thought, peculiar views of the individual, twists of language, or even sacred traditions from a remote past. Bacon's scientific work was itself slight. Nevertheless, coming as he did at a time when men's minds turned toward the investigation of natural phenomena, he exerted and has continued to exert a tremendous influence.

IV

SCIENTIFIC PROCEDURE: INSTRUMENTS OF PRECISION

Mechanical Inventions

CERTAIN instruments which are peculiarly a part of scientific investigation make it more than a process of reasoning. These instruments have been devised to make observation more accurate and conclusions more dependable; and most striking of all of these are the mechanical inventions which have opened up new worlds to the investigator. Galileo's invention of the telescope with the subsequent improvements which have been made has revealed the dome of heaven no longer as the abode of starry divinities as the ancients saw it, but a place of infinite space containing countless whirling worlds which before were invisible. The perfection of the compound microscope brought under man's observation the world of the infinitely minute and raised anew many questions as to the origin of life; and the discovery of the cells of which living tissue is composed has made possible a comprehension of life hitherto undreamed of.

Besides such epoch-making inventions as these, the laboratory of the physicist, the chemist, the biologist, and now the psychologist, is full of complicated apparatus to aid him in his work. One important group of instruments is for the purpose of recording movements so that they may be studied at leisure or observed by others. This is done by means of a slowly revolving smoked drum and tambour. A photographic film is even more valuable for such a graphic record, as for example, that of the heart beat, of respiration, of muscular fatigue, of eye-movements in reading, and the like. The camera is of real value in taking the place of a verbal report of conditions, whether they be of geologic formations, botanical specimens, or, as it has been recently used, of facial expressions for the study of the emotions which they reveal.

Another group of instruments consists of those which make for greater accuracy in measurement. Among these are the balance, thermometer, voltmeter, ammeter, barometer, chronoscope, stopwatch, etc. Many of these instruments are as valuable in educational investigation as they are in the natural sciences.

Quantitative Measurement

The appearance of these many mechanical contrivances emphasizes the one great difference between ordinary observation and scientific observation, a demand for accuracy. It is all very well for the sufferer to say that it is hotter to-day than it was yesterday, or that he feels hotter; but this will not do either in meteorology or as a scientific medical diagnosis of fever. Greater accuracy is necessary. It is all very well for the successful housekeeper of the older generation to tell how she makes a cake by putting in a pinch of this and a handful of that, and stirs till it is about right; but a scientific household economist is not satisfied with any such method to say nothing of the waste it would mean in a large baking establishment. It is all very well for the amateur hunter to aim at the bear generally, and if he is lucky, the bear will either drop or run away; but military science traces the trajectory of a shell with the most exact precision. It is all very well for the ancient Greek to see his gods and goddesses in the starlit heavens; but astronomy measures the distances between the heavenly bodies and traces exactly their movements through space. It is all very well for the

fight enthusiast to tell how his champion avoided his opponent's thrust just in time; but the psychologist measures the quickness of different kinds of reactions to the thousandth part of a second. In the same way the educator must have done with his slipshod guesswork, his 'it seems to me's,' and his 'I should think's.' If he is going to get any further than his predecessors he, too, must talk in figures. He, too, must have his accurate methods of measurement, and such measurements as these are now being developed in the form of tests and scales, which we shall consider later. They are mentioned here to indicate their correspondence to the other measures in the natural sciences.

But even before any of these instruments can be perfected, units of measurement must be developed. We who take our inches and yards, our quarts and bushels, our ounces and pounds, yes and our liters, meters and grams so as a matter of course seldom stop to think of the long period of difficulty and uncertainty which elapsed before these became standardized. Irving Fisher, in his effort to demonstrate the practicability of a new unit of measure in economics, the stabilized dollar, tells very interestingly how the foot was originally the length of the chieftain's foot, and

the yard the length of his belt, and how a revolution might easily play havoc with the national system of measures. Only gradually have these arbitrary measures gained acceptance and become standardized, and those who have been following European exchange can see the difficulties in the way of this standardization.

Then besides the simple linear units, and units of weight and capacity are the more complicated ones which the natural sciences have evolved, such as the light-year of the astronomer, the kilowatt-hour of the physicist, the foot-pound of the mechanical engineer, etc. The very fact that these have appeared along with the development of the different sciences is reason for inferring their necessity. And this inference can be substantiated by asking the workers in these fields if they couldn't get along just as well without them.

It is therefore natural to see similar developments in the field of education as the search for answers to its problems comes to take over the methods of science. One of the earliest and most important units was that employed by Binet — the mental age. This unit of measurement probably has done more than any other one thing to hasten the development of scientific method in

education. Other units, some of them dependent in part upon it, are the intelligence quotient, the educational quotient and the acomplishment quotient — units of measurement which are now in the process of being standardized. Other illustrations can be drawn from the fields of statistics, as for example, the median, the standard deviation, the probable error, the coefficient of correlation. For an educator not to know the significance of these units of measurement is as unfortunate as it is for a physicist not to know what is meant by an ohm or a wave-length, or for a biologist to register ignorance when a micron is mentioned.

The Experiment

The experiment is the most characteristic part of scientific procedure and most essential to it. It is apt to be futile, it is true, without the careful observation that must accompany all scientific investigation, without the mechanical inventions, and the units of quantitative measurement. But these are recognized and necessary aids to it.

Another essential in the use of experiment is the *trained experimenter*. He must be trained in the knowledge of the field in which he works,

and he must be trained in the technique of handling the intricate apparatus which is at his disposal. Few would deny that the chemist should be well trained not only that he may present trustworthy results, but, as in the case of his working with high explosives, that he may not be a menace to those around him. He must be trained to detect the most minute deviations in his test tube or on his slide, deviations which the ordinary observer would not even see, much less consider significant. But just such slight changes as these in movement, or color or form may be the things to bring on a new heaven and a new earth, if they are observed and their implications appreciated.

Just as the trained experimenter in the natural sciences is the only one who is to be relied upon to make accurate observations and to appreciate their implications, so the trained investigator in the field of education is the only one who should take any part in the pursuance of truth in his field. The importance of this fact is beginning to come home to school administrators who have experienced the social equivalent of a chemical explosion. Persons unskilled in the proper administration and interpretation of tests have set out on a campaign of measurement in a school

system, with the result that incensed parents have resented the classifications in which their young hopefuls found themselves; other things have happened frequently because of avoidable errors, which have tended, unfortunately, to discredit the whole measuring movement in the eyes of the people of such communities. Only in rare cases is the classroom teacher qualified to administer tests, because of the need for uniformity and exactness. Only in rare cases is the classroom teacher qualified to interpret tests, because of the many factors which have to be taken into consideration. Even with the most expert handling, errors are bound to creep in, though it seems a safe assumption that these are far fewer than are those made under older systems of classification. Through the increasing literature which is now available, and through the rigid training which universities are now offering, classroom teachers may now become properly fitted both to administer and to interpret certain of the standard tests, particularly the scales measuring school achievement.

The *sine qua non* of the experiment, however, the thing which distinguishes it from everything else, is its *isolation and control of the factors* in the situation. In the experiment of Pasteur already

quoted,[1] he allowed every influence that could possibly be exerted *save one* to be brought to bear upon the water of one flask — electricity, magnetism, ozone, or any imaginary force. That one which he kept away was the dust of the air. All the conditions were identical in the case of the other flask except that the dust could reach the infusion. In the former the bacteria did not appear, in the latter they did. He had thus isolated the factor of the dust. He controlled its entrance by means of the crooked-necked flask. He could conclude that the bacteria appeared in the water not by spontaneous generation but by the influence of the dust of the air.

The coin and the feather dropped at a different rate to the earth, and it might be concluded that this was due to the difference in their weight. But there is another factor that can be isolated and controlled, and this is the factor of atmospheric resistance. When the coin and the feather are placed inside a glass tube and the air removed by means of an exhaust pump, the influence of this factor is removed; when the tube is reversed, they fall together to the other end. It is thus possible to conclude that the original

[1] Page 34.

difference in their rate of fall was not due to their differing weights, but to the greater resistance offered the surface of the feather.

The final characteristic of the experiment is that it can be *repeated* at will. Any person with the requisite amount of training and technical skill should be able to follow the method exactly and arrive at the same results. The experiments cited above can be repeated with comparative ease; others require far more time and apparatus. The reason that some of the experiments quoted to support the doctrine of the inheritance of acquired characteristics are not taken as sufficient evidence in support of this doctrine is the fact that other biologists have not succeeded in repeating them. This suggests that some error has crept in undetected, some factors in the situation have not been isolated and controlled. The essential features of the experimental method, then, aside from careful observation and quantitative measurement, are the trained investigator, the isolation and control of the factors of the situation, and the repetition of the experimentation.

Rules of Scientific Thinking

There are certain rules [1] of scientific thinking which have gradually been evolved during the last thousand years, adherence to which helps to guard against error, the sin which doth so easily beset the experimenter. These rules of the game like certain of the mechanical devices, like the experiment itself, are really instruments of precision, and must constantly be borne in mind not only by the investigator himself, but by those who would follow and profit by his investigation. This is more rather than less true in the field of education where a great many so-called 'contributions' are of dubious value.

1. *Give first place to facts.* This is one of the oldest of the rules, having been stressed by Roger Bacon in the twelfth century. Roger Bacon "called the science of his time from authorities to things, from opinions to sources, from dialectic to experience, from books to nature." [2] He was little more than a voice crying in the wilderness at the time, but his rule has never been questioned by scientific men.

[1] Cf. Cooley, W. F.: *The Principles of Science* (Henry Holt & Co., 1912), p. 42, ff.

[2] Windelband: *History of Philosophy* (The Macmillan Company, 1901), p. 344.

Although this was one of the first rules to be formulated, it is one which is frequently neglected even to-day. The rule compels us to give first place to facts, but it is often very hard to give up a pet theory even in the face of the facts. We are sorely tempted to try to make our facts fit our theories, particularly if these theories are our own invention or if they are of long standing. It is easy to consider a stubborn fact merely as an exception to the rule, and be content to keep both the rule and the exception. But sooner or later one will have to go, and usually it is the rule we have made and not the fact we have discovered. An exponent of a present-day religious cult is reported to have said that facts to her were but as grass to be brushed aside and trampled on in the attainment of the greater truth.

In contrast with this is the scientific attitude which may be illustrated by a quotation from Darwin whose prolific mind suggested innumerable hypotheses which he tested by the host of facts which his indefatigable labor collected: "I have steadily endeavored to keep my mind free so as to give up any hypotheses, however much beloved . . . as soon as facts are shown to be opposed to it. Indeed I have had no choice but to act in this manner, for, with the exception of

the Coral Reefs, I cannot remember a single first-formed hypothesis which had not after a time to be given up or greatly modified." [1]

The inquisitors of Galileo were all for continuing allegiance to their theory believing that religion would suffer by the defection of any. But the stubborn facts had their way, and while the Ptolemaic theory for which they so firmly stood has gone into the discard, religion seems to be about as potent a force as ever. It seems highly probable that the facts of biology will be likewise superior to dogma, and incidentally, be quite as impotent in the destruction of religion.

Education, having so recently ventured forth from the kindly protection of authority, has particular need to guard against the infringement of this rule. There are so many ideas as to the sacredness of things as they are, from 'the little red schoolhouse' to the 8–4 organization of grades, and from the time-tested 'school subjects' to the doctrine of formal discipline, that it is too easy for the educator to view the facts turned up by surveys, by standardized tests, by carefully conducted experiments as merely grass

[1] Darwin, Francis: *Life and Letters of Charles Darwin* (D. Appleton & Co., 1887), vol. I, p. 83.

to be mown down before the progress of his beguiling theories.

2. *Don't multiply theories unnecessarily.* This, again, is a very old rule dating back to the fourteenth century. It was formulated by William of Occam thus: "*Entia non sunt multiplicanda praeter necessitatem.*" Theoretical existences must not be increased without necessity. The need for this rule was felt because it was found that people were inventing new theories to account for new phenomena. Occam wanted to cut away a lot of this unnecessary mental construction and see if a few, established theories would not account for many of the new discoveries. Hence this rule was long called 'Occam's Razor.' It is sometimes, also, called the 'Law of Parsimony.' Its operation makes for greater simplicity and unity.

An illustration of this rule can be taken from the field of psychology. Various forms of so-called mind-reading have been known from the earliest times. Many fantastic theories have been put forward to account for the phenomenon, as for example, the one that the thought is projected through space in the form of an invisible cloud from the thinker to the reader. As over against that, psychology has evolved certain

very well established doctrines such as that of the action of the neurones in receiving stimuli by means of the sense organs and responding in various ways. With Occam's razor we can cut away the extra theory, and see if the phenomena cannot be explained on the basis of the one which we already have, and which explains a great many other phenomena. Study of cases of mind-reading then results in the discovery of what is called muscle-reading, or the interpretation of very small movements of the 'thinker' which no one notices but the 'reader.' Here we have an explanation on the basis of the other doctrine so that in this case it is unnecessary to multiply theories.

3. *Avoid the fallacy of the reification of abstractions*, or considering subjective phenomena as objectively existing things, or even as causes. In its cruder or more obvious form, this is *personification*, and can be illustrated by the mythology of any primitive people. The phenomenon of the thunder was observed and explained by the hurling of thunder bolts by Zeus who then was the Thunderer, or the cause of the thunder, as was Thor among the Norse people. The harvest was a most important period of the year, and this was controlled by Ceres, who one time in her wrath

caused the streams to dry up and the growing grain to become parched and to shrivel. The harvest and nature's fertility were personified, reified, made a being who was considered the cause.

In its more subtle forms this fallacy is not so easy to detect.[1] Certain learned men not so long ago published abroad the statement that they had succeeded in weighing the soul because they noted a slight decrease in the weight of the body when death came. They therefore unblushingly announced that they had measured in ounces the weight of a metaphysical conception. Descartes' locating of the seat of the soul in the pineal gland is more to be pardoned than that. It would be like weighing the nebular hypothesis or finding the diameter of goodness. Present-day spiritualism is likewise falling into the error of reification. True, many who investigate the phenomena of ectoplasm, and of table-tipping, and yet are not convinced that all cases are fraudulent, reject the 'spirit hypothesis.' But even in doing this, they are in danger of talking about the objectivation of thought, of putting a thought or a mental image under the microscope, which is all too like locating it in a neurone. When the thought has

[1] Cf. Wallas, Graham: on "Political Entities" in his *Human Nature in Politics* (Houghton Mifflin Company, 1909).

once achieved its ectoplasmic reification it then becomes potent, easily enough, and moves furniture around at will.

Gravity is another phenomenon which is easily reified. Gravity is the name given to the phenomenon of the attraction that bodies have for each other. But when we say that this attraction, this falling of the apple to the ground is caused by gravity, we are creating a god, and our next step should logically be to implore this Gravity to cause another apple to fall as soon as we have finished eating the first!

The history of psychology is not free from this error. The various abilities and traits from memory and reasoning power to docility and amativeness were reified, given a particular pigeon hole in the brain by the phrenologists, and considered as potent entities by the faculty psychologists. Though there are no longer any faculty psychologists among the psychologists, they are still to be found on college faculties. Even to-day we hear talk of reasoning power, strengthening the memory, will power, and the like, as if they were not names for certain groups of particular reactions, but were separate, well-nigh corporeal beings whose energy might be enlisted in our behalf.

Only the hardy and the foolhardy have the temerity to enter the instinct controversy. Therefore let this alone be said. There is danger of committing the fallacy of reification when an instinct is regarded not as a grouping of various unlearned reactions, but as a separate force which compels the reactions. To say that a child plays with blocks because of his instinct for manipulation is saying no more than that this child plays with blocks because he plays with blocks and other things like them. The instinct of manipulation, then, is not an outside force which is responsible for the child's behavior; it is merely a name for a particular kind of behavior. To assume that it is such a force producing the behavior is to accept but one of several interpretations of the behavior.

4. *Regard analogy as a source of suggestion, not as proof.* A well-constructed analogy forms one of the most specious forms of false reasoning to trip the unwary that a special pleader for any cause has at his disposal. An analogy is a partial similarity. To reason from analogy is to infer that because two things are known to be alike in certain respects they are therefore alike in certain other respects. A child learns many lessons thus. The nursery kitten scampers on four legs, is

white and fluffy. Out-of-doors an ugly tempered pup appears which answers to the same description. The child toddles up to him, saying 'nice kitty,' but the analogy is incomplete; dissimilarities appear at once. The cur growls, snaps at the child and makes off. But the child has not learned to distrust analogies. He grows up and is about to cast his first vote. The political orator dramatically calls attention to the fact that he came from the same town as most of the members of his audience, and that together they should push on to victory. Probably he says 'shoulder to shoulder.' The youth casts his vote and helps to elect the candidate, who straightway makes a very comfortable income from the extra-salary perquisites of his office, leaving his fellow townsmen none the richer. The similarity of birthplace is no earnest of a likeness in ideals. The analogy was incomplete.

Another form of this type of error is the case of a man who meets a stranger who looks like his best friend. Here is a partial similarity — external appearance. He therefore concludes that this stranger has the other qualities of his friend; so he walks up to him, makes himself known, and engages the man in conversation. At once differences appear, and on leaving perhaps the

man discovers that he no longer has his purse. The errors of a much advertised system for reading character at sight are of this kind, but are on a larger and more systematized scale. Certain mental and emotional characteristics are supposed to go with certain shapes of countenance or certain coloring or skin texture. It is therefore inferred that all persons having these shapes of head, this coloring and skin texture, have these certain mental and emotional characteristics.

Various experiments are easily open to this kind of error in their interpretation. For example, it is found that white rats learn the four sections of a maze in a particular way more rapidly than in any other. It is a glaringly false analogy to infer that human beings will learn the four stanzas of a poem more rapidly in a similar way. And yet, though this is not proof, it presents a most interesting hypothesis, a valuable source of suggestion for further inquiry.

Another form of this analogy appears when the laws and theories from one field of knowledge or activity are brought in to explain phenomena in another field. We sometimes wonder how Froebel, sensible as he was, could have spent so much time in speculating on the peculiarities of

the various crystals and drawing conclusions from their geometric regularities for life and morality. In his autobiography appears this passage: "The crystal world, in symbolic fashion, bore unimpeachable witness to me, through its brilliant unvarying shapes, of life and of the laws of human life, and spoke to me with silent yet true and readable speech of the real life of the world of mankind."

The arts, with the greatest ease, can talk in the language of each other. A warm color, discordant shades, colorful harmonies, living marble, eloquent bronze, vigorous melody — these and even more striking combinations are to be found in the literature of any of the arts. But scientific thinking must confine its expression to the field in which it is working, for otherwise no exactness would be possible. For this reason, the rich and variegated vocabulary of Freud is immediately antipathetical to the scientifically trained man, when he talks about such things as impulses in the subconscious guarded by a censor. This fallacy is sometimes called the 'fallacy of irrelevant interpretation' or 'imported principle,' and becomes dangerous as soon as the symbolic or hypothetical character of the terminology is forgotten.

5. *Apply the test of agreement to both positive and negative cases.* No conclusion can be accepted unless it is self-consistent, that is, agrees with itself, agrees with the facts more completely than any other interpretation, and agrees [1] with the known facts and previously discovered laws. It is clear that this last criterion might occasionally have to be abandoned in case new facts are presented which make the older conclusions untenable. In the case of the younger sciences, this occasionally if not frequently happens, but here as well as in the more well established sciences revolutions are not as frequent as young investigators sometimes think they are going to be. The theories and laws are extended a little here and modified a little there, but as a whole they remain about the same. Only on the fringes of the sciences, in the realm of the hypotheses is there frequent give and take.

6. *Scrutinize all statements purporting to be true.* This rule Descartes regarded very carefully. "I have taken pains," he says, "never to accept anything for true that I did not clearly know to be such . . . and to comprise nothing more in my judgment than what was presented to my mind so clearly and distinctly as to exclude all ground

[1] Cf. p. 48.

for doubt." In this way, Descartes guarded himself against building upon common sayings, authoritative formulations of Church or State, or mere opinions as if they were true, until he had scrutinized them carefully so as to pass on their truth or untruth himself. If teachers and educators could apply this rule regularly, the educational hobbyist might have to retire or find some other employment. Many statements pass for true because they were uttered by some famous authority or are written in some ponderous book, statements which may have been true, possibly, when they were uttered or written, but which will bear scrutiny before they are indiscriminately applied to-day. For many people, to see a thing in print is to believe it. This gullibility of the public for the printed page presents a real obstacle in the path of the clear thinking that is needed in a democracy. Signs of a better time are appearing, however, not only because this rule of Descartes in the guise of critical reading is being more and more employed in the schools, but also because the newspapers have taken advantage of their power to such a degree that they are coming to be more and more distrusted.

All assumptions fall under this rule. Geometry, for example, assumes the truth of certain

mental constructions which it cannot prove, viz., the axioms and the postulates. But these are not passed by hurriedly; they are viewed carefully from every possible angle. It were well if all assumptions in scientific investigation were given as thorough an airing. Even though some of them cannot be completely demonstrated, even though there is doubt about some others, the extent of the uncertainty is recognized, the weakness of each link in the chain is ascertained, so if any break comes, it is possible to locate the point fairly accurately and give it particular consideration.

Aside from the primary postulates of physical science [1] there are less general assumptions against which the worker must constantly be on his guard. One of these, in the field of educational research is the theoretical probability curve. It is rather terrifying, sometimes, to consider the number of statistical calculations which assume the normal frequency curve. Another source of error in this field is the unwarranted assumption of a random sampling; there may be some selective factor at work, such for

[1] For example, the uniformity of nature, the rationality of the universe, the objective reality of the physical world, and the actuality of space and time.

instance, as the elimination of the less gifted in the upper grades and high school which makes measures of high school students far from applicable to youth at large. Another illustration of a dubious assumption is found in the basis of scoring the true-false examinations. The guesses of a large number of pupils would be about half right and half wrong; but there is no assurance that the guesses of *each* pupil will be half right and half wrong.

7. *Avoid basing conclusions on too few cases.* Induction proceeds, as we have seen, from the particular cases to the general statement of uniformity concerning them. Though authorities differ on the point, it is not usually considered induction when all the cases possible can be observed. To be induction there must be what is known as the *inductive leap.* Because an hypothesis holds true in all of the hundreds of cases studied, we 'jump to the conclusion' that it will hold true in *every* case. In the simple illustration used previously, we study hundreds of leaves, and every one is green. Inductively, we lean to the conclusion that all leaves are green. The danger in the inductive leap is readily seen. For a little later we may come upon the yellow one and the red one.

The great care that the investigators in the natural sciences have shown in carefully avoiding this source of error by the most painstaking observation can well be emulated by workers in the newer fields of the social sciences.

But a still more vigorous warning needs to be given. If every one based his conclusions on a number of cases, the results would be more satisfactory than they now are, when people are so prone to make all inclusive generalizations on the basis of just one case! The young man is disappointed in love; so all women are fickle. It rains the day of the picnic; so it always rains on a day when a picnic is planned. The Chinese laundryman lost some collars for a customer, so he never can trust a Chinaman.

Reasoning like this is so common in daily conversation that it is quite unnecessary to multiply illustrations. Aside from committing the grievous error of generalizing from too few cases, the additional error is made of *neglecting the negative cases*. The person does not record the number of faithful women of his acquaintance, the number of days it did not rain for the picnic, the number of Chinamen whose treatment of him has been beyond reproach.

The following anecdote illustrates this fallacy

of neglecting the negative cases in a rather unusual way. A young man was demonstrating the strength of a premonition. He told of how he was traveling in a trolley in a certain city, when ahead of him a building that was under construction seemed to sway toward the road where his car was about to pass. In his mind's eye he could see the building totter and crash down upon the car, crushing the passengers who were thus confined and helpless. He could hear their agonizing screams. So sure was he of what was about to happen that he started to his feet to get off the car before it was too late, but he seemed unable to move. The car came nearer to the building. It was directly in front of it. The man cringed. The car moved on smoothly toward its destination. The building had not fallen. A rather disappointing conclusion, perhaps. Exactly. That is the kind of story that doesn't usually get told. That is the negative case that is usually neglected. If the building had fallen, if there had been a seemingly miraculous escape, the narrator might easily have been convinced of the potency of a premonition, and that story would have been his favorite to bring out when tales of the mysterious and the occult were being told.

8. *Be consistent and coherent;* that is, reason correctly avoiding deductive fallacies. These are enumerated and illustrated in any standard work on logic with their Latin and English names. Only one other will be mentioned. This is the kind of *non sequitur* called *post hoc ergo propter hoc* — 'after this, therefore on account of it.' This is mentioned because it is so frequently met with, and because it is so insidious in its operation. A great city sets out on a campaign to improve its schools. The taxpayers are deluged with publicity, a big building program is inaugurated, junior high schools are built, and other reforms are put through. The board of education then announces that a large per cent more children are retained in the junior high school than the other organization was able to hold. Surely this increase in school population came *after* the junior high school program had been put into effect, but the cause of the increase might also be found in the greater interest of the people in the schools, in the added vigilance of the truant officer, the appeal of new buildings, and many other factors. A mother in another city whose son was attending the junior high school for the first time, complained that he was ruder than he used to be, and that he didn't play

at home so much, preferring to go off 'goodness knows where' with a lot of boys she didn't know. She complained to the principal of the effect the school was having on her boy. It is hardly necessary to suggest that this change in the behavior of her son, though it came after his promotion to the junior high school, would probably have come just the same if he had gone on into the usual seventh grade. The changes which she deplored came *after* his transference to the other school but not *on account of* it.

9. *Use precise terms.* Scientists have always endeavored to express themselves exactly so as to avoid all misunderstanding and ambiguity. One source of inexactness lies in the use of *metaphorical language.* Excellent and necessary as this is in literary expression, that a passage may be interpreted in terms of the reader's emotional experience, it is a stumbling block to clarity when the intellectual processes alone are enlisted. The true scientist is, therefore, repelled when he sees such a passage as the following, taken from a recent advertisement: Some people "try to make the grade of success with the WILL-POWER cylinder not firing at all — or with a sooty spark-plug in the PURPOSE cylinder." It is pardonable because of its 'appeal' value, perhaps, but as an explana-

tion of the thought processes it is impossible. Many volumes on a variety of subjects ranging all the way from will-power to Freudianism and from auto-suggestion to various Oriental cults, and classed by the book-sellers as psychology, have recently been published which seek to appeal to the popular mind by means of such flaring figures. The following is a fairly mild illustration, taken from a recent treatise on auto-suggestion: "He who can control his own mind by an iron will, and say to the Thoughts which he would banish, 'Be ye my slaves and begone into outer darkness,' or to Peace 'Dwell with me forever, come what may,' *and be obeyed*, that man is a mighty magician who has attained what is worth more than all the earth possesses."

To gain greater precision, a *technical terminology* has grown up in the different branches of science. This is sometimes the despair of the layman when his progress is blocked by such terms as 'hyper-brachycephalic' man or 'bathmic' evolution. He cries out in despair for a book that is written in English. No wonder that a great deal of popularized science has appeared which has been of uneven worth. But just such technical terms, as substitutes for round-about expressions, and as symbols for ideas previously

unnamed, have made possible the rapid progress of science during the last few decades. We cannot imagine physics or chemistry without its complicated formulæ. We can but rejoice in a similar movement in education. It is an indication of a possible acceleration in the rate at which problems now pressing in this field will find their solution.

Exact *definition* is a necessary corollary to a technical terminology. Although definitions seem a dreary waste to the beginner in any science, and various pedagogical methods are employed to soften their harshness, no one would deny their necessity. Science has no time for the argument which ends: "Oh, if that is what you meant, all right. I agree with you."

Both psychology and education are handicapped by being forced to use a great many technical terms which are also used in common speech. For example, the word 'soul' has largely been dropped from psychological discussion chiefly because it is practically impossible to find two persons who agree as to the meaning of the term. Other words which tend to ambiguity in this respect are idea, instinct, mind, will, evolution, brightness, character, personality. In the eleventh century there was a similar

looseness in the use of such words as mathematics, astronomy, astrology, and magic, which were used interchangeably by some authors. Progress in the direction of exact and uniform terminology is necessarily slow. It is, therefore, a source of gratification when terms with which the educator deals begin to assume a definite and uniform meaning. The increasing exactness in the definition of such terms as curriculum, junior high school, acceleration, retardation, and moron are glimmerings which presage the dawn of a new day.

A fourth means for greater precision is to be found in the use of *quantitative measures*. These are discussed elsewhere [1] but are mentioned here because they are quite as important as the avoidance of figurative language and the use of a technical terminology and of careful definition, if slipshod thinking and fruitless speculation are to be replaced by the dependable conclusions which science seeks.

Scientific Knowledge and Other Knowledge

From what has been said, it is clear that the difference between scientific knowledge and other knowledge is one of degree and not one of

[1] Page 64.

kind. But the difference is a wide one, nevertheless.

Scientific knowledge, in the first place is *free from personal bias*, whether that bias be due to the weight of authority, the pride in one's own opinion, or the consequences to oneself. The scientist is not a special pleader for his cause, except as he pleads that the facts which he presents and the conclusions which are based upon them be given their due consideration.

Scientific knowledge, in the second place, is *exact*. With its instruments of precision, its quantitative measurement, its employment of experiment and its careful precautions against error, all handled by trained experts, it presents its data with a care for detail that is lacking and even unnecessary in many other fields.

Scientific knowledge, in the third place, is *verifiable*. Its experiments can be repeated and its statements scrutinized critically by any one with adequate training. Its facts are not of the past like historical events, but are *principles operating uniformly at all times*.

Scientific knowledge, in the fourth place, is *systematized*. A science has no place for heterogeneous, unrelated facts and theories no matter how well they may be established. Everything

must be understood in its proper relationship to everything else, whether that be a relationship of cause and effect, of similarity, or whatsoever it may be. And these various items must hold together in their different classifications into an organic, systematic whole.

We are now in a position to examine more carefully the recent changes in education, and to inquire if they are scientific, to what extent education employs the scientific method, and to ask if education itself may be regarded as a science.

V

SCIENTIFIC METHODS APPLIED TO EDUCATIONAL PROBLEMS

If one casts about for evidence that the influence of custom, authority, and opinion in education is on the wane, he has not far to look. On every hand are the signs pointing in that direction. It is significant that the American Association for the Advancement of Science recently made room among the affiliated sciences for an education section, Section Q. This is, however, merely a recognition of the increased output of studies of a scientific nature in the educational field.

A still more palpable indication of this activity is to be found in the multiplication of publications carrying quantitative and experimental studies in the field of education. The National Bureau of Education and such foundations as the Russell Sage, the Carnegie, and the General Education Board, as well as various experimental schools, seem to vie with each other in turning out studies of one sort or another, of uneven value, to be sure, but yet far away from the pronouncements of custom, authority, and opinion. Nearly a score of journals, monograph series,

and yearbooks [1] regularly publish studies of importance which involve the use of the fundamental characteristics of the scientific method. Besides these there is an ever-increasing number of books which present information derived from research in the fields of tests and scales, educational psychology, curriculum-making, and school administration. At the very least, these things bear witness to a truly amazing development of interest and activity in the direction of educational inquiry free from the fetters of the past and hard in pursuit of new truth.

Methods of Psychology — Used to Study Children

The genealogy of the college of education is easily traceable to the department of philosophy in the European and early American universities. The professor of philosophy was expected to give some lectures on psychology and some on peda-

[1] For example, *American School Board Journal, Educational Administration and Supervision, Elementary School Journal, Journal of Educational Psychology, School and Society, School Review, Journal of Educational Research, Teachers College Record, Contributions to Education* (Teachers College, Columbia), *Supplementary Educational Monographs* (University of Chicago), *Educational Psychology Monographs, Harvard Bulletins in Education, Harvard Studies in Education, Yearbooks of the National Society for the Study of Education, School Efficiency Monographs, School and Home Monographs.*

gogy. Then psychology and education grew to such size that they split off from the parent stem and became a separate department. So rapid, however, was the development of subject-matter, like that of the various natural sciences which were formerly grouped as one course called natural philosophy, that in many centers psychology and education became separate departments, the latter in many cases growing into a separate college in the group of colleges in the university.

The period of union of psychology and education, a period which continues even to-day in many of the smaller colleges of this country, was far from being detrimental to the best interests of education. On the contrary, the two fields have the whole learning process in common, and it is natural, therefore, that many of the earlier scientific studies of this essential portion of the work should have been made by psychologists.

"We do not understand children!" exclaimed Rousseau. It is to make good this deficiency which he so deplored that the psychologists have come forward in increasing numbers, endeavoring to free themselves from the habits of thought decreed by custom and by authority; endeavoring to escape from the influence of easy generaliza-

tions and of proverbs quoted for generations, which are about as effective as the Anglo-Saxon charm for bewitched land; and endeavoring to get disentangled from empirical knowledge, which is about as unsatisfactory as the methods of fertilization of the soil of the American Indian.

At one time, not so very long ago, children were considered as miniature adults, in all things like them except for size. The early Renaissance artists painted children with heads bearing the same proportion to their bodies that the head of the adult bears to his body. Long after this it came to be discovered that children are differently proportioned beings in every way — physically, mentally, emotionally. It was, therefore, a great victory when educators began talking about 'the child' in contradistinction to 'the adult.' Only recently has there been reflected in the language usually employed the realization that children differ amongst themselves nearly as much as they differ from adult human beings; that while generalizations about 'the child' are often of value, nevertheless they lead to grievous misunderstandings. And while people have always known that children 'are just as different as they can be,' they have not known exactly in what ways they are different and to what ex-

tent. One generalization was as good as another, and one generation was little ahead of the preceding. It is, therefore, with the intention of emphasizing this realization of individual differences scientifically studied that this section is entitled not "Methods of Psychology — Used to Study *the Child*," but "Methods of Psychology — Used to Study *Children*."

1. *The questionnaire.* One difference between the astronomer and the psychologist is that no one has any grounds for questioning what the astronomer says about the stars, but everybody thinks he knows more about children than the psychologist. It was to capitalize this information on a grand scale that the questionnaire came into use in psychology, having been borrowed from those who used it to compile figures and make reports concerning the census, immigration, and labor.

This method was employed to the full by the late G. Stanley Hall of Clark University in the compilation, among other things, of his two monumental volumes on adolescence. The method was to circularize various people and ask them certain questions concerning their previous ways of thinking, their interests, enjoyments, and when these began, their motives, and the

like. School teachers in particular, being a fairly unified group and interested in these questions, were a very fruitful source of information. Perhaps in this era of the reaction against the indiscriminate use of the questionnaire, we are too apt to minimize its importance. It at least presents a fairly accurate record of the beliefs and recollections of the person who fills it out conscientiously even though these may not always be accurate representations of what transpired years before. But more particularly, it serves to focus attention upon certain problems and certain aspects of those problems, and certainly in the case of Hall's *Adolescence*, a wider interest in the problems of this period has been created than could be imagined without it, and his conclusions have acted as a real stimulus to further investigation.

But there are certain disadvantages that far outweigh the advantages. In the first place, his dicta have until recently been too much taken for granted; they have not stimulated enough investigation. Secondly, usually a third to a half of the persons circularized do not answer the questionnaire. It is assuming too much when it is supposed that these persons' answers would correspond in every way to the answers of those

who did respond. Furthermore, the group circularized is all too apt to be a special group, not a random selection, so that we are in danger of falling into error when we make our inductive leap and conclude that all people are like that. There is considerable reason to suppose that the youth of school teachers is not a safe basis from which to generalize concerning the youth of business men, mechanics, shopgirls, bootleggers, and clergymen. Thirdly, the report is biased, not only because the questioner is apt to select the reports that fit his theories, but also because there is a tendency on the part of a person filling out a questionnaire to give the questioner what he is looking for. This may be purposely done, or it may be quite unconscious on the part of the writer. He may and quite probably will rationalize his acts, and report motives by which he may think he was guided rather than those which actually decided his conduct. And lastly, incidental memory is too fickle a thing to trust in scientific matters. Experiments inquiring into the reliability of testimony have all but discredited the eye-witness. And when we are asked to recall at what age we first enjoyed music, for instance, our memory is apt to play us false. A particular concert may stand out

in our memory for purely incidental reasons: we may have worn a new hat, or perhaps the governor sat in a box — and previous concerts are quite forgotten. And which one of us remembers that sweet music which lulled us to happy rest in our earliest years, the mother's cradle song? No, our memories are not to be trusted. And though we may report a lot of things on our questionnaire which make very interesting reading when they are compiled, there is no one to say which are true and which are false, and a real science can put no confidence in them.

Anthropometry. Alongside of the activity of sending out, filling in and recording questionnaires another and more promising kind of measurement was developing. This came from the activities of the physiologists and more particularly the medical men and those concerned with public health. Height, weight, chest-depth, chest-expansion, arm-flexion, head-girth, — these and many other measurements have been made for some time, often by the directors of college gymnasiums in order that corrective exercises could be prescribed, and better physical conditions built up.

These measurements have one important connection with education in that consecutive

measures of the same individuals give us our exact information concerning physiological growth. With these exact measures it is possible to make studies of the relation of the physical development of children to such things as their chronological age and mental development. These measures have been still more refined so that with the use of the X-ray the process of ossification of the wrist bones is exactly determined, a measure which has been found useful as an index of anatomical growth. Other relationships have been studied as, for example, the ratio of height to weight to detect malnutrition and so guard against its consequences. Others, on the other hand, are of little or no value. Various cranial measures have been demonstrated to show no particular relationship to mentality except in such instances of feeble-mindedness as micro- and macrocephalis. Similar relationships between height and intelligence have been sought, but no credence is placed in them except by those who follow after the charlatans.

3. *Measuring human reactions.* A much more profitable technique, however, is the measurement of human reactions. On the more definitely physiological side, such as the activities

of the smooth muscles and glands, much more remains to be done; the studies [1] of these responses and their relation to the emotions are pioneer efforts of great promise. On the psychological side, the development of measurements of the time and accuracy of human responses has furnished the main highway down which the greatest psychological advances have come, and along which the greatest discoveries of the future will probably be found.

Careful measurements of the *reaction time* of such simple responses as depressing a key when a light is flashed give way gradually to measuring such things as tapping-rate, speed of cancellation, and memory span for digits.

When this measuring movement was joined by another, great progress was possible. This other was the development of the so-called *tests of intelligence.* Although Ebbinghaus was probably the first person to employ a creditable test for intelligence, a variation of the completion test as we now know it, it was Alfred Binet who devised the complicated instrument which now bears his name, and which was adapted to children of different ages. Various revisions were

[1] For example, Cannon, W. B.: *Bodily Changes in Pain, Hunger, Fear and Rage* (D. Appleton & Co., 1915.)

made of the Binet-Simon scale, the last one being completed at about the time of his death in 1911. Psychologists in other countries have since revised the scale, translating it and adapting it to the needs of the particular countries concerned, notably Stern in Germany and Cyril Burt in England. In this country the revision of Terman, called the 'Stanford Revision,' has had the widest use of any individual measure of intelligence, and the adaptation of certain of its tasks by Otis so that an intelligence examination could be given to a group paved the way for the development of the Army Tests in 1918.

It is naturally not my purpose here to trace the development of the testing movement, but only to point out that these measures and many others now available have been worked out with the strictest regard for the care and accuracy that science demands, and furnish surprisingly reliable measures of the native ability of children of approximately the same culture as those for whom the particular scales were devised and tested.

So fruitful has the investigation been in connection with such tests as these that an hypothesis which is well called a theory now has been evolved — the theory of the constancy of the

ratio between the mental age of any particular child and his chronological age. On the basis of this theory, therefore, it is possible from the intelligence quotient, as this ratio is called, to predict with considerable accuracy in regard to the future school and life success of that child. As a theory it has yet to be tested out thoroughly, and like others, it is subject to revision. At the very least, it is a very useful measure which can serve as a basis for further studies for the proper educational guidance of a child.

There has been considerable hue and cry raised of late about the undemocratic character of such a measure which, its opponents claim, brands some children as stupid and condemns them to a life of inferior achievement. Of course, this is about as true as saying that the yardstick brands the five-foot man as shorter than the majority of his fellow beings. The intelligence tests do not make or unmake brains any more than the yardstick makes height, or the scales weight. It simply measures what is there. And it is not the first instrument to be so used. School marks have long been similarly employed without exciting any such solicitude, and those who are concerned about the social prestige of one who has a low intelligence quotient never

worried much about the habits of failure which the school inculcated in keeping him at tasks too difficult for him, and punishing him because he couldn't do them, by all sorts of ingenious torments like the red-ink mark of failure, being kept after school during a ball game, or kept off the team because his work was not up to the standard. They were not concerned about the aversion that grew within him for things of the mind, an aversion which grew into hatred because each year he was pushed into tasks which he could not do, and surpassed by children younger than he.

Paralleling the intelligence tests in their historical development during the last decade is the formulation of standardized *measures of school abilities*. Stone, Ayres, Courtis, and Thorndike, were the pioneers in this work, and their carefully developed scales to measure the extent of children's ability in handwriting, spelling, arithmetic, silent reading, composition, etc., have been supplemented by the work of Woody, Gray, Haggerty, Van Wagenen, Otis, Gregory, and many others.

Here, again, we have nothing new but the *accuracy* and *freedom from personal bias*, and *standardization* so that a score in an elementary-school subject in one school can be compared with the score in another. There have always

been teachers' marks, but they have not been useful for comparison in different schools because different teachers had different subjective standards of excellence. Ninety per cent for one teacher might be the equivalent of seventy per cent of another; and even the passing grade in such supposedly exact studies as mathematics is a movable feast. The teacher's mark is about as useful for purposes of comparison as 'a few' would be as a unit of measure in place of a dozen.

So complete is the literature on the subject of scales and measures of school ability that there is need here but to call attention to the gradual perfection of these instruments in the movement toward the precision of measurement which a science demands and without which there is little gain. They are a development in the educational field of the method of measurement in psychology which places an individual in a certain controlled situation and then measures his response in terms of time or of accuracy.

4. *The rating scale.* Still another method which is employed by the psychologists and which has been used of late by educators is the rating method. It is used to get the benefit of more than one person's judgment about such abilities and traits as do not lend themselves easily to

measurement by the more standardized measures discussed above. The rating scale as it was employed for the selection of officers in the Army was too complicated a method in view of the results to have the wide acceptance it at first promised. Other schemes of rating character-traits have been devised, particularly as they may be used in the selection of teachers.[1] They mark a step in the direction of accuracy above the biased judgment of one individual in evaluating the traits and abilities of a particular person for a particular job. But clearly this method falls far short of the accuracy demanded by a scientific investigation bent on discovering the facts about such an elusive thing as personality.

5. *Experiment.* Realizing this, a few experimenters[2] have endeavored to attack these problems in a more scientific fashion. It is probable that the near future will see remarkable developments in this direction. In addition to such

[1] For example, Schutte: *Rating Scale for Teachers.* World Book Company.

[2] For example, Downey, June: *The Will-Temperament and Its Testing.* World Book Company, 1923.

Moore, H. T., and Gilliland, H. R.: "The Measurement of Aggressiveness." *Journal of Applied Psychology* (1921), vol. 5, pp. 97–118.

Trow, Wm. Clark: "The Psychology of Confidence: An Experimental Inquiry," *Archives of Psychology* (1923), no. 67.

pioneer work, and in addition to the quantitative studies in education using methods evolved by the psychologists, certain other investigations have been conducted of a rigidly experimental nature. James's classic study of the transfer of training in memorizing is historically one of the first if not the first actual experimentation of a laboratory character in this country. The later experiments of Woodworth and Thorndike in the beginning years of the century attracted wide attention and have been followed by countless experiments in the same field. These will have to be followed by many more before the troublous point of the extent and manner of transfer is decided to the satisfaction of all.

As sad a quantity of useless academic talk is expended on this topic as upon any in the whole field of education. The direction it usually takes is that some one in tones of awe explains how much he profited by a certain course of study, often the classical course. Avoiding the cynic's reaction that he might have been a bigger and better man if he had not taken it, it is easy to see that a person is no judge of the value to him of a particular kind of work. It would, indeed, be unfortunate if the rigid linguistic training incident to eight years of intelligent study of the

Latin language was not reflected in increased facility in the use of the mother tongue. But how much that facility is increased, say, in comparison with the way it might possibly have been by some other training for eight years; or what part the teacher and the native intelligence of the student played in this benefit, are questions which opinion can never answer. And to argue that because eight years of Latin are appreciated by a brilliant mind, a dull child shall take one year of it to get some benefit, is of course the most patent and glaring of familiar fallacies.

The current theories of transfer, that of transfer through identical elements (Thorndike), and that of transfer by generalization (Judd), do not seem so antagonistic as some would have us believe. For the present, educators must be content with them and the results of experiments to date,[1] and wait patiently for what the future will bring forth. The method of science is not rapid; it takes longer to formulate a scientific law than it does an opinion. But we have seen that for a number of reasons the results are more trustworthy.

[1] These experiments, as well as the theories of Thorndike and Judd are admirably summarized in Starch: *Educational Psychology* (The Macmillan Company, 1921), pp. 191–255.

Another group of carefully controlled experiments relates to the progress of learning. The pioneer work in this field was done by Ebbinghaus, whose invention of nonsense syllables to control the factors of previous knowledge and chance association on the part of the subjects resulted in the Curve of Learning, which is really a scientific law in graphic form. The early rapid rise, the daily variations, the plateau, the physiological limit, — these characteristics have been found by other experimenters as the experiments have been repeated with other materials by Book, Bryan and Harter, Swift, Starch, and others. This work is rather at a standstill just at present, waiting for the more rapid and more enthralling development of the tests and measures and scales spoken of above. But this work on learning will be picked up again, and will profit by the development of measures of other kinds of learning which, it may be found, may not correspond to the more strictly mechanical memorizing and acquisition of motor skills which fall along the present familiar learning curve.

To Ebbinghaus, likewise, is due the device for measuring the amount and extent of forgetting, a most baffling thing to measure, by the simple expedient of measuring the time taken to relearn

a passage and dividing it by the time taken to learn it in the first place. This has given us our law of forgetting as shown by its characteristic curve, its initial rapid fall followed by a gradual fall and at last by a long nearly horizontal line indicating a period of almost indefinite retention of a small portion of what had been learned. It has given us our knowledge in regard to over-learning with its important corollaries in education.

Other directions of experimental inquiry of the psychologists which are closely related to educational problems are the study of eye-movements, which has its direct bearing upon the teaching of reading, and the study of the effects of fatigue which has important school-room implications. These problems lend themselves to the careful, experimental investigation described earlier, permitting of the elimination and control of the factors concerned and the repetition of the experimentation.

Methods of Medicine — Used to Study Children and Homes

1. *The clinic.* The health of school children is beginning to receive the attention which is its due, so that in most of the larger schools proper

medical attention can be given to the pupils in a systematic way, and those whose handicaps are less noticeable may have the care they deserve as well as those with more severe defects. Examinations of eyesight, hearing, teeth and tonsils are usually a part of the routine required by law. In most cities the best that medical science can give is available not only for the rich, but for the poor as well. As Terman [1] says, "Too often tuberculosis steals the child, or spinal curvature deforms him while we wrangle over rival methods of teaching him geography or grammar or spelling."

2. *The case history.* When a wounded man came back to this country and was taken into one of the army hospitals, there usually came with him a record of the previous medical attention he had received, the various tests made and their results, the record of operations and findings and opinions of the different physicians who had had him in charge. Naturally, these things were of great value to those who had to diagnose his case and prescribe treatment in the American hospitals.

A similar thing is proving very successful in

[1] Terman, L. M.: *The Hygiene of the School Child* (Houghton Mifflin Company, 1914), p. 15.

the schools. These records may or may not be of a medical nature; the similarity is in the method, not in their content. In many of the more advanced school systems, research bureaus are established as a part of the public school system. In the files of these bureaus are to be found, in some cases the records of every child in the system, in others the record of each whose case is in any way unusual so as to need special attention because of failures of one sort or another, because of disciplinary troubles, and the like.

These records are not important because they contain the teachers' marks for these children, though they may contain these. They are important because they contain the results of the standardized tests which have been administered to the pupils — the intelligence quotient, the percentile standing in other intelligence tests and in educational tests, and in many cases the test paper itself. If trouble is reported for any particular child, here is his record, and his case can be dealt with intelligently on the basis of it. But these case histories are important for another reason.

On each one of the medical case study blanks is a place for a disease history of the family. The physicians may be content with the patient's

account of this. But the social workers, like the educators, have borrowed the method of the case history. One of the things which they do is to investigate the home conditions of any delinquent whose case they wish to handle intelligently. In this study, the work of the physician, the social worker and the psychologist as a student of mental hygiene come close together.

A child seems listless in school, lacks interest in his work, fails repeatedly. A study is made of the case. It is found that his mother is dead, his father is a teamster who takes the boy to a wagon restaurant for a breakfast of two cups of coffee and a doughnut at five o'clock each morning, after which the boy carries papers until schooltime.

A girl is caught in petty thefts of money. Investigation shows that she is allowed no spending money by her parents, though they have enough to allow her some. She wants to be like her mates and treat them once in a while if she has to steal from them to pay for the treat! Another who plays truant, it is discovered, feels uncomfortable in school because she hasn't as good clothes as the other girls have. A boy fails to pass, his parents scold him unmercifully and whip him. He wonders what's the use, and likewise runs away from school. Various unsatisfactory

compensatory reactions are often due to just such conditions in which the child is humiliated in some way. Then, too, nervous, irritable children, it is often found, come from homes where they are nagged by their parents, or frightened, or punished by one of the parents and secretly rewarded by the other. The conditions producing the symptomatic behavior with which the school must deal are often not easily discovered, and when discovered correction is frequently difficult partly because of the stubborn nature of such disabilities and partly because the unfortunate home conditions are not under control of school authorities.

Clearly, the good old rough-and-ready way of making children work and whipping them if they don't is as archaic as it is brutal; and in all fairness an effort toward an intelligent handling of these cases as the knowledge about them is gradually collected is the very least that can be expected of schools in this particular.

A Method of Sociology — Used to Study Curriculum Content

The social survey. In former times it was practically possible for one pupil to master all that the school could teach, and at some periods of

history it was almost within reason for one man to know all that was known. But the former things have passed away. To-day we see the curricula of the schools crowded with great quantities of subject-matter jostling each other, each demanding a place of precedence. The happy days when the lower schools taught the three R's and the higher schools and colleges Greek, Latin, and Mathematics are no more. Perhaps philosophy is responsible for the change — the camel's head protruding into the tent of the contented Arab was soon followed by such other portions of the ungainly animal that the Arab found himself out in the cold. Natural philosophy was followed by the many separate departments which gradually appeared owing to the enormous increase of knowledge brought about by scientific investigation. Only a few years before the Civil War an instructor at Yale devoted two or three lectures to the principles of electricity assuring his students that this knowledge would in all probability be sufficient for them to understand any developments along that line that might take place during their lifetime! Then moral philosophy likewise took to dividing like a cell, and ethics, psychology, education and other departments appeared.

Long before this, the older subjects had to justify themselves or be shoved out into the cold. The argument concerning their cultural value had to be supplemented by the disciplinary argument, and thus a foothold was maintained. Then the sciences with their practical knowledge and close connection with the life of the day were in their turn elbowed by courses in history, music, drawing, manual training, and other innovations. We find the peculiar phenomenon of the natural sciences in their turn forced to justify their place in the curriculum on the basis of the disciplinary value of the training involved!

Meanwhile, each specialist is convinced that his subject is the most important in the curriculum, and might almost be the only one that is really necessary. The poor administrator, in addition to having to keep the peace between his various departments, must meet the needs of the children and of society as he sees them.

Little more can be done than has been done by appealing to authority. The specialist sees his subject from the point of view of the subject as a whole in its logical completeness and beauty. He cannot see it through the eyes of the child, nor from the standpoint of the best interests of children in view of the lives which they will have

to live. Few would question the advisability of the study of any great department of knowledge in its logical completeness by advanced students. But many are beginning to question the value of such study for immature children. Even Euclid, the perfection of system if there ever was one, is being mutilated piecemeal, on the basis of the rather obvious hypothesis that simpler portions of geometry might well precede much more difficult portions of arithmetic and algebra.

The development of a course in general science and of a general course in the social sciences for children of the junior high school period — grades seven, eight, and nine — marks a most important step in the reorganization of the curriculum that is now under way. But what shall be selected for these and other courses — least common multiple, cube root, interest, keeping a check book, the boundaries of the states, the products of Brazil, the spread of disease, a city's water supply, the supreme court, Tammany Hall, army military campaigns, the waste of national resources, the rule for forming plurals, Julius Cæsar, George Washington, Tom Paine?

The authorities have had their way in the past, and have included things which seem to arouse

little interest on the part of the pupils, and which seem to furnish little or no useful information or training which they can employ after they are through school. Granted that these two considerations are of importance, interest and utility, the careful study which characterizes the scientific method is now indispensable. What are the worth-while things that are at the same time interesting? What are the things which can be taught in the schools for which the pupil will have some use when he is through school? The former problem is one to be answered by study in the school; for the latter we must turn to society. Ask the bank employees what the public should know about banking. Go to the magazines and newspapers, and find what the reader must know to read intelligently concerning affairs of current political and social and artistic interest. Go to the parents and discover what mathematical processes they actually use in their daily work. Granting that they would use a few more if they were able, it is surprising how many chapters of arithmetic would be eliminated if this were the sole criterion. Discover the mistakes that people make in their English, in their arithmetic, in the other things they do, and let the curriculum bear more heavily on

these things. Investigations of this kind have been made by persons who have had regard for the rigors of the scientific method. But more investigation is needed. Since all the available knowledge cannot go into the school curriculum, an intelligent selection is the least that can be expected of the school in this particular, and this intelligent selection cannot be made on the basis of the historical importance of the different subjects, nor upon the basis of the opinion of authorities alone, but it must be made on the basis of a careful scientific analysis of society to discover what are its needs.

Methods of Economics — Used to Study the Schools

1. *The industrial survey.* As schools have increased in size beyond the dreams of the early settlers of this country, and as an increasing number of subjects are placed on the different curricula demanding various kinds of apparatus and equipment, and as the demands for hygienic and artistic buildings have become more insistent, the problem of cost has grown rather than diminished during the last score of years. Various finance studies were made early in the present century, but these have given way to the

more comprehensive undertakings known as school surveys. The school survey involves a careful study by experts of the whole school system of a city or rural region, its equipment and its needs in relation to such factors as the population, the character of the people in the different portions, their race and vocations, the available funds which can be expended, and the most immediate needs.

Clearly, intelligent progress is impossible until the situation and the needs are adequately known, and this collection of facts as contrasted with such airy opinions as are often expressed as to 'what we need' is as characteristic of the method of science as the experiment.

2. *The statistical method.* We have now viewed some of the more important methods of collecting data and measuring them quantitatively in order to make for a better knowledge of children and their homes, of the subject matter, and of the schools themselves, so that the process of education may on the basis of these facts, be more intelligent and more effective. It remains only to speak briefly of certain devices employed by economists and mathematicians in handling such great masses of data as these methods bring in.

If all the children in the sixth grade of a city school are measured for their ability in the fundamental processes of arithmetic, and we are presented with the scores of each child, we are baffled by the great number. We do not know how to interpret them until they are grouped for us perhaps graphically, and the distribution compared with the theoretical probability curve of Gauss, or at least until we have computed some one of the averages, the median, the mean, or the mode — the carefully devised measures of *central tendency.* We must also have a measure of *variability* to tell us whether most of the scores are grouped close around the average or are widely scattered on each side of it indicating that many of them are very good and many are very bad. For this measure we have the range, the mean deviation or the standard deviation. When we have the distribution drawn, and have the figures representing the central tendency of the scores and the variability of the scores, then we are ready to compare this curve and these figures with similar ones from other sixth grades in other schools to see if they are better or poorer. If they are much poorer, the matter needs investigation and correction. Perhaps the children are more stupid, perhaps teaching methods need

to be improved or the curriculum altered; or perhaps the teacher needs to be released.

Now if this same sixth grade was also measured for arithmetical reasoning, or the ability to solve problems in which the pupils had to decide for themselves whether they should add, subtract, multiply, or divide, it might be interesting to find out if the children who did well on the former test were the ones who did well on this other. If all the children ranked the same on both tests, and this held true in every school; or if they were twice as good on the second as on the first, or three-into-the-square-root-of-two times as good, we should have a scientific law, a statement of uniformity like the law of gravitation which says that bodies attract each other directly as their masses and inversely as the square of the distance between them.

Clearly, such an universal statement of relationship could not be expected between such measures. The children who were good on one test would tend to be good on the other, and the children who were poor on the one test would tend to be poor on the other. This much would be satisfactory for the non-scientific mind, just as it is sufficient to say that to-day was quite a bit warmer than yesterday. But suppose we want

to know exactly how the scores compare. Here is where the very useful coefficient of correlation comes in. This figure derived by a fairly complicated mathematical process, states the extent of that relationship. It varies between + 1.00 and − 1.00. The former figure, + 1.00, would represent a condition in which the scores of all children on both tests were the same; the latter, − 1.00, would represent the equally preposterous condition in which the highest child on the one test was the lowest on the other, and so on for every child.

Now if this coefficient of correlation is somewhere between .50 and .90 (which is about as high as it ever gets) we have a definite relationship established. Children's scores on the fundamental processes correlate with their scores on arithmetic reasoning about +.30. If this is found to be so wherever it is tried out, we have discovered a uniformity just as truly as if we talked about inverse squares and other relationships. Abilities move together and not at random, here this way and there that way, but together according to certain fixed laws.

Through the medium of these measures we can discover these relationships and tentatively formulate them with as much enthusiasm as ever

a uniformity was discovered and formulated by a Galileo, a Newton or a Pasteur. Naturally the work of Galton, Pearson, Gauss, and Yule has borne fruit. Naturally those who adapted these statistical measures to educational purposes, Cattell, Thorndike, Rugg, Kelly, Otis, Thurstone, and others have uncovered a mine of opportunity and potential energy for the formulation of new truth which cannot but have most important consequences for the theory and practice of education.

VI

CONCLUSION

The Field of Education

Upon first glance it might strike one that education is merely a happy combination of contributions from different sources, and that in itself it has no independent being, no *raison d'être;* that it is a mere parasite, sucking the strength of certain sciences and living merely as they live. This opinion might be confirmed when one considers on the content side the part that is played by the subjects themselves, the Latin, biology, history, and other subjects. If education borrows its methods for the acquisition of truth from the natural and social sciences, and its subject matter from the great bodies of knowledge which as administered in diluted form are known as subjects, where does Education itself come in!

Let us consider the last point first. While the number is gradually decreasing under the vigorous onslaught of brutal facts, there are still those who maintain that a knowledge of a subject is all that is essential to teach it, and the

more knowledge the better teaching. This is one of those half truths that make so much trouble in the world, and which are sometimes found in places where one would least expect to find them. To make it a whole truth, it must be stated thus: *Other things being equal*, the more knowledge of a particular subject a teacher has the greater will be his ability to teach it. But the other things may or may not be equal. Specialists in the different departments of Latin, biology, history, and the rest are doubtless right when they say that to do the best teaching as full and complete a knowledge of these subjects as possible should be possessed by the teacher. No educator would take exception to this, insofar as knowledge is a factor in the teaching process. *But knowledge in and of itself will not transfer automatically from teacher to pupils, regardless of its extent and precision.*

Of course specialists in these different departments will be expected to do their share in furnishing a full and complete knowledge of their specialty to prospective teachers. Given this knowledge on the part of an instructor the lesson of the day takes on new meaning in the light of fact and anecdote which the teacher can contribute. Pupils' questions need not be put off

with a peremptory 'We'll come to that later,' or 'We haven't time for questions now,' or that still more easily recognizable evasion, 'If you look it up yourself you will remember it longer.' Other things being equal, adequate knowledge will make excellent teaching.

But what are these other things? Ask any group of college students, after you have gained their confidence, what they think of some of the scholars who meet them for the purpose of instruction. 'Yes, funny old bird, gets awfully excited about his stuff, but nobody knows what he is talking about.' Or of another, 'He puts everybody to sleep; they call his course the Pullman.' Or of another, 'Yes, he knows his stuff all right, has written a couple of ponderous and scholarly volumes on the subject; yes, he's an authority,' this with a touch of pride, but then with a smile, 'He's a joke, though. I've tried, and some of the others have, but we can't get anything out of his course.' These testimonies are selected at random, and anybody could multiply them by the score. *The value of scholarship is lost because the method is lacking.*

If these things are true in college, how much more true are they in high school and elementary school. And for our illustration we need not

resort to the extreme cases of disorder, the insolence, or the wholesale failures which result from a lack of teaching skill. Things that the person who is not an expert supervisor would not notice, a little wrong emphasis here, a failure to allow quite enough discussion there, insufficient drill, a poor lesson assignment — faults such as these make the class period but little better than worthless because pupils just fail to get the fact, or the point of view, and the teacher doesn't know it.

A successful salesman, a powerful speaker, a great violinist must have more than a knowledge of his product, his subject or his music. He must have the skill derived from a long period of careful training. In the same way *the able teacher must have his subject-matter, of course; but he must also have the skill to make his subject matter effective.* He may have a greater native capacity than another and need relatively less training. But born teachers are few, and the schools must have thousands. And whatever the natural ability, be it great or small, it is bound to be improved by proper training.

These 'other things' which seldom are equal, begin to assume greater importance. There seems to be a subject-matter of education quite apart from that of the particular *subjects* which

are taught, and teaching method is all that has been mentioned. Nothing has been said of special supervisory skills, or training in educational administration, nor yet of the historical and philosophical backgrounds of education.

Now, let us consider the first question raised, namely, is there a field of educational *investigation* which is separate from that of the different sciences whose contributing methods have been discussed? It will at once be recognized that the *method of science* — observation, hypothesis, and verification with the use of various mechanical and mathematical instruments of precision — is common to all sciences. Furthermore, the materials of each of the different sciences are not the exclusive property of that science. The physiologist borrows methods, instruments, and principles from the biologist, and the biologist is just as free to appropriate what the chemist uses if it helps him to solve his problems. In studying vision, we consult the physicist about the refraction of light, the physiologist about the structure and function of the eye, the chemist about the nature of the visual purple of the retina, the neurologist about the neural and cortical connections, and the psychologist about the facts of sensation and perception.

Whatever contribution, then, that any science can make the educator may legitimately appropriate if it will help him in the solution of his problems, if it will apply to his field. And what is his field? What are his problems? Anything which has to do with the furtherance of the process of education. And what is the process of education? Here we could digress at length were it a part of our purpose. Instead, let us put it briefly thus: From the psychological viewpoint, it is the making of useful changes in the habits, skills, knowledge and ideals of individuals. From the social viewpoint it is making for better adaptation to and control of the features of the natural and social environment. Here is the field of education. To these ends should all knowledge be canvassed to assist in the process.

Experimentation in Education

But this does not mean that this borrowing is all that there is to education. True, it employs methods of collecting and accurately measuring data used by these sciences, but it puts them to work in its own field. In addition to this it does some investigating on its own account.

In the first place, it investigates individuals. It does this in a more thorough way and inves-

tigates more individuals and to more practical purpose than the psychologists, if left to themselves, ever would have considered necessary or practicable. The nature of these investigations has already been suggested. It includes everything from the careful laboratory examination of individuals to the administering of standardized tests and scales to large groups, and thereby finding the performance of different individuals on the different measures with a view to educational placement and vocational guidance.

In the second place, education investigates class groups. Some of this work has attained considerable prominence as, for example, the experimentation which set out to find the transfer value of habits of neatness formed in connection with the written work of one school subject as it carried over to the papers of another subject where neatness was not demanded. A device to help control the various factors of such experiments on a number of people known as the *control group* has been found to be of great value in reducing errors. This control group in all essential particulars save the one being tested is given the same experience as the other.

It may be illustrated by an experiment in the psychological laboratory. If the object of the

experiment is to determine the influence of caffeine upon efficiency, one group of subjects is given the drug and the other, the control group, is not. None of the individuals knows whether the mixture he takes contains the drug; in all other respects, their experiences are the same during the course of the experiment — food, hours of sleep, amount of school work, exercise, and the like. When the different tests of efficiency are then applied at varying intervals it is possible to compare the performance of the two groups to see if it differs relatively from their performance before the caffeine was used, and so become relatively sure that any difference in that performance is due to the influence of the drug.

Important experimentation of this character to determine the advantages of different methods of teaching is being conducted in various experimental schools. The outcomes desired are formulated, tests devised to test them, and these tests are given to the different groups which have been taught by the different methods. Thus something more tangible than opinion is made available for making a choice of methods.

In the third place, education investigates whole schools. While in many experimental schools such experiments are performed as have

already been discussed, these experimental schools are themselves conducted to test out certain hypotheses in which their directors have great faith. To a person not acquainted with these schools this seems a dangerous thing to do. It doesn't seem fair to experiment on the helpless children. But in most cases the teachers are experts, the equipment is in every way complete, and more attention is given to the development of each individual child than in the ordinary school. Besides, parents usually pay a considerable amount of tuition that their children may be under the direction of these specialists. On the whole it seems quite as fair to have specialists experiment in a systematic way as to have beginners without the requisite knowledge, training, or experience learn to teach by experimenting on children, a condition which has long maintained, and against which there has been little complaint from the laity.

Professor John Dewey is probably more responsible than any other one man for the hypotheses which are the guiding principles of some of these experimental schools. One of these hypotheses is that a truer education comes from an adaptation of the school materials to the life interests of children. So we have our shops and

laundries, our general science courses and our clubs. Another hypothesis, and one not incompatible with it is that a higher development of the individual child comes from greater freedom; and so the desks are unscrewed from the floor, children walk about as they please and converse at will much to the dismay of visitors familiar with the old régime. The school, instead of being an absolute monarchy, becomes a largely self-regulating democracy, which, as it happens, is the social and governmental order in which the children will move when they leave school. Another hypothesis is that the work unit rather than the time unit is the better; and so we have our Dalton laboratory plan testing this out.

Now who shall decide upon the truth of these hypotheses which, it may be, have a right to be called theories? Clearly only he who has made exhaustive studies of the results of the different forms of management and organization of the different experiments. And these studies are not the kind made by certain men of prominence who are reported to have gone to Europe to 'study conditions,' and whose acquaintance with Europe comes from seeing it from the car window and talking with the *concierge* at the hotel. These studies are made, or they must be made if they

are to give us the truth, by means of careful measurements and comparisons of performance in this school with that in a similar school run on a different plan. Because this is extremely difficult in view of the expected results, which are often statable not in terms of particular schoolroom skills but in terms of ideals and points of view, these principles upon which the schools are run are still theories. And these theories will be generally accepted or rejected according as the rigorous method of science is employed in measuring and evaluating them.

Limitations of the Scientific Method in Education

1. *Limitations of all the sciences. Science does not determine truth unmistakably and for all time.* As has already been pointed out, many things which the world has held as true have been discarded, and many things which we now believe will undoubtedly be disproved. In view of this, there are some who lose patience with science. They do not like to feel that they continually have to be keeping up with something like the styles. They prefer to have something that is truth once and for all time. These persons usually find greater satisfaction in the pro-

nouncements of mystics which are made with less troublesome investigation and which purport to hold true forever. They are satisfied with the *ipse dixit* of persons who are quite often the founders of religious sects and denominations. In other words they become followers of authority.

Goals may thus be set up which may or may not bring advantage to them and to society at large. It is for scientific inquiry to ascertain this as soon as the situation presents itself as a problem, and as soon as the proper technique has been developed. When, however, these *ex cathedra* pronouncements are made concerning the *facts* of science already established whether they be of astronomy or of biology, sociology or education, the authoritarians are on dangerous ground, and science is all too apt to brush them aside, quite deaf to their protestations.

At this point it might be well to ask the old question, What is truth? We may limit our discussion to the presentation of two answers. The first is: Truth is what one thoroughly believes. The second is: Truth is what works. Conviction and workability — these are two very different criteria representing two very different philosophic viewpoints.

The first view can be applied to matters of common sense, the things which seem true, the things we always consider true, and the things we are convinced are true. These things may run all the way from belief that a horsechestnut in the pocket will keep away rheumatism to belief in the inherent goodness of mankind. If you believe it with all your heart, if you act upon it, for you it is true. Much that we believe must be based on this principle; it is belief without proof, and so many important things cannot be proved.

But one of the things that makes us hold to such a belief is that it works. Was the world flat before men sailed around it? Probably not. From the absolute point of view of any one individual who thought so and acted upon that belief, it was flat. But now the things that people could do if the earth were round have been done. People have sailed around it, for example. The theory that it is round works. This is the basis upon which scientific truths are built, and is called *pragmatism*. If every person who carried a horsechestnut escaped rheumatism, and every person who did not had it, the cure could be said to work. The truth would be established pragmatically that horsechestnuts keep off rheumatism.

Similarly, the experiment of Pasteur which has

already been referred to 'worked.' Predictions based upon it also 'worked.' And largely as a result of his investigation we pasteurize milk and we vaccinate to prevent an epidemic of smallpox. These things have been found to work out in practice.

What is meant by this limitation of the sciences — that they do not determine the truth unmistakably and for all time — is that some things which work for a while may cease to act according to predictions under certain other circumstances. A new hypothesis, then, has to be formed, or a new theory promulgated and tested, which will more fully square with the facts.

What is sometimes considered as another limitation of all the sciences is that *they do not furnish objectives and ideals.* For example, a science of chemistry makes possible the manufacture of chlorine gas, but does not determine whether it shall be used to destroy armies or to cure a cold. A scientific time-and-motion study shows what is the most efficient way to do a certain piece of work, but it does not tell us whether it is right to subject a worker to additional strain and monotony. The science of chemistry cannot discourse upon the ideals of warfare; it can only furnish facts and predict

consequences. The sciences of psychology and economics cannot speak concerning the ethics of certain industrial processes and their relation to the worker; they can only present certain facts and predict certain consequences. It is no concern of the scientist which set of consequences is chosen.

The same position is frequently held in regard to ideals in the field of education, where they are commonly called objectives. Various lists of objectives of education have been formulated such as that of the Commission on the Reorganization of Secondary Education [1] which lists health, command of fundamental processes, worthy home membership, vocation, civic education, worthy use of leisure, and ethical character. Given these objectives, it is sometimes contended, educators can set about the task of evaluating them scientifically and embodying them in school practice. The ideals themselves, however, must come not from science but from philosophy, ethics, and religion.

It must be admitted that this is a very plausible view of the situation, and that it is widely held. And this is no more than natural in view of the

[1] *Cardinal Principles of Secondary Education.* Wash. Government Printing Office, 1918.

narrow and uneven advances which have characterized man's inquiry into the nature of the world in which he lives. As a result of this, science has come to be viewed as particular *subject-matter* — as chemistry, physics, biology, etc. — and not as *a method of solving problems wherever these problems may chance to rise.*[1] When science is viewed as subject-matter, ideals and objectives cannot but be regarded as separate. Chemistry cannot be looked to to abolish war, or psychology and economics to banish industrial discontent. But when science is viewed as a *method*, ideals and objectives become the direct outgrowth of its application. *The cure for the deficiencies of science is more science.*

Let us illustrate this point with the health objective, although any other might be used. The older view would be that this objective finds its source in the words of persons with a religious or philosophic training who say that health is an ideal which educators should strive for in their improvement of the schools. The position here maintained is that health, as an objective, is a direct outcome of the application of the method of science.

[1] For an application of this view, even to the ethical field, see Givler, R. C.: *The Ethics of Hercules*. Alfred A. Knopf, 1924.

The first step in this process, we have seen,[1] is seeing problems. In different schoolrooms certain difficulties confront the teachers. Some pupils do not pay attention when they are spoken to, and some will not learn to read. Others "talk through their noses," or let their mouths hang open, and are exceedingly indolent. Still others, who are thin and pale, are lazy and fall asleep when they should be studying. These and similar problems have presented themselves to every teacher. In an earlier day they were all dealt with in a similar and summary fashion. A whipping was good pedagogy, and religion at least furnished no other ideal. Indeed, it aided and abetted corporal punishment, for it taught that children were "conceived in sin and born in iniquity," and that the mortification of the flesh was the sole way to overcome the original mistakes of Adam, and to bring displeasure to a very real devil.

The second step is the discovery of the solution. Other suggestions as to the best ways to meet these difficulties began to arise as the facts came to be known. Some of these, when tried out, seemed to produce more desirable results. The children who wouldn't pay attention were

[1] Above, p. 38.

discovered to be slightly deaf and were seated nearer the front. Those who couldn't read, it was found, could hardly see the printed page, and glasses were prescribed. Throats were examined, and diet was inquired into. But these suggestions could not have come to the schoolroom had it not been for the development of the science of medicine which had discovered the facts concerning poor hearing, faulty vision, diseased tonsils, and malnutrition, had shown the consequences of these conditions, and evolved remedies. Attention to these matters increased with the increase of scientific discovery.

The third step, then, is the gathering together of all these things, previously viewed as separate problems, into one generalization which is in every sense an hypothesis. This hypothesis might be stated as follows: If steps are taken to keep pupils healthy, they do better work in school and afterwards. Here is the generalization arrived at as other hypotheses are arrived at. It becomes a working principle which, in practice, comes to have all the force of a natural law. Instead of springing fully panoplied from the brain of some philosopher or mystic, it has come as the result of a long process. On the one hand are the countless school problems

which have been demanding attention. On the other are the careful scientific investigations not only in the field of education but also in chemistry, biology, medicine, etc., which have presented the facts and the consequences and have thus aided in the discovery of the solutions.

There are some who consider that the desire of people for healthful schools is no part of the scientific method. By the same token, the desire of investigators for the truth is no part of it. Both of these desires are given elements in man's nature. They are data just as other observable phenomena are data and are so considered in the process of testing an hypothesis.

Thus any objectives and ideals, whether they appear in the field of education or in the realm of the phenomena with which chemistry deals, or psychology or economics, come as a result of solving many problems. They have value if the scientific method is used in evaluating the suggested solutions to these problems, and in testing the hypotheses which are formulated. *Science, regarded as method and not as subject-matter, instead of being limited by the inability to furnish objectives and ideals, in reality develops and formulates them.*

2. *Limitations of the biological sciences.* When

we take up the study of the phenomena of life, we find a certain unpredictability which is most baffling, and which makes careful investigation and the establishment of law difficult. When Halley predicted that a comet would come around again at a certain time, the comet appeared according to schedule. When the psychologist predicts that the small child will come around again at meal-time, he has a good chance of being right. But the boy may have gone to a baseball game and may not show up until an hour later; or he may have decided to run away and so not turn up at all. If you put a quart of water on the scales in Maine and another in California, the weight in each case will be the same. But if, after giving intelligence tests, you put the upper ten per cent of the children in the sixth grade of a Maine school in one group, and the upper ten per cent of the children in the sixth grade of a California school into one group, your two groups will differ widely in the range of their intelligence.

Then there is, in addition, the difficulty in isolating and controlling the factors for a careful experiment. A pupil fails in his schoolwork. How do we account for it? Low intelligence, laziness, neglect at home, poor health, too much

time at parties or at sports? One or all of these things may have a bearing on the boy's failure, but to control the factors so that it is possible to say exactly how much influence each has is next to impossible. However, the method of partial correlation is being employed to separate the influence of simultaneous contributing factors when those factors can be measured, and thus this difficulty is being overcome.

3. *Limitations of education as a science.* Apart from the limitations which education shares with other sciences, there are some handicaps which though not peculiar to education are unfortunately all too commonly operative. The first of these handicaps is the hang-over of the influence of authority and speculation. These have an even larger influence than is necessary. The second is too meager scientifically derived information, too few data, too few accurate measures, so that it is often necessary to fall back upon authority and opinion. The third of these handicaps which is now being corrected as rapidly as may be, is the deficient scholarship and training of too many educators. Some of these, unfortunately, are the ones who do the most advertising, and as a result the whole progress of education is called into question or misunder-

stood by those who judge education by these persons only.

Education More than a Science

There is little to be gained in debating the question — Is education a science? We have demonstrated that it employs the scientific method in the search for new truth, and is so building up an organized body of knowledge even apart from the pronouncements of authority and of opinion. If this makes a pure science education is one. If it does not, education is not a pure science.

But it does more. It employs the principles so derived for the solution of its problems. If this makes an applied science, education is one. If it does not, education is not an applied science.

But it does more than this. It employs individuality in the selection of principles and methods in particular cases. That fine thing not yet satisfactorily analyzed called personality that the musician must have, and that the artist must have, and which each must somehow get into his work, the teacher also must have. Just as the musician must know the laws and principles of music, and the painter those of color combination and design, and employ these, so too

must the teacher know the principles of education, must have a knowledge of children and schools and processes gained from other than empirical sources. And to the extent that this thing called personality is operative, education is more than a pure science, more than an applied science. It is an art.

The study of the history of education up to the present time is an inspiring study because it traces the crystalization of the ideals of different periods of history. Each generation desired to make of the next generation what it had desired to be and had often failed in being. So it organized schools which should carry out this work. But it is a sad study, too, for it is the history of blind trial and error, of mistakes made over and over again, of useless waste, of sad neglect. And there is nothing to indicate that this condition of affairs would not have continued indefinitely if a new light had not been thrown on these problems because of the efforts of those individuals who were willing to break with the past, and employ the method of science to help answer their questions for them.

It is easy to contrast the one-room New England grammar school building with the beautiful school plants of the present day. It is

easy to contrast the condition of affairs which maintained when Horace Mann gave up a promising career of the law and took out his horse and buggy and drove up and down New England attacking that deadly apathy which is worse than open opposition and awakening public opinion to the need for normal schools, with the conditions of the present when there are colleges of education in all the great universities.

And to what end? To the end that the highest ideals may be made corporate, and may operate in the institution of the schools. To find out how they may be best made to operate, and to train persons that this knowledge may become effective — this is the task, a task which can be satisfactorily performed only as educators learn to employ the method of science in the solution of their problems.

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OUTLINE

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